MARITIME IMPROVISED EXPLOSIVE DEVICES: A THREAT BASED TECHNOLOGY STUDY

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14. ABSTRACT Over the last thirteen years, the world saw an increased use of improvised explosive devices (IEDs) by violent extremists and terrorist groups. Due to the simplicity and availability of IED making material, any willing person with limited knowledge can make IEDs. Given that the surface of the earth is eighty percent water, the maritime environment is a likely threat domain for terrorist activities. Navy Explosive Ordnance Disposal (EOD) has the sole capability in the Department of Defense (DOD) for countering the maritime improvised explosive device (MIED) tactical threat to United States national interests and security. EOD divers, with limited equipment, are still the primary resource to render safe the waterborne explosive threat. The wars in Iraq and Afghanistan proved that robotics and unmanned tools are essential to EOD operations ashore for safety and standoff from IEDs. Unfortunately, use of robotics in the maritime environment for EOD operations is relatively new and unproven. The primary thesis question is: "How can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment?" This thesis identifies a capability gap in safely countering MIEDs and recommends a materiel solution in closing the gap.						
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ABSTRACT

MARITIME IMPROVISED EXPLOSIVE DEVICES: A THREAT BASED TECHNOLOGY STUDY, by Lieutenant Commander Jonathan L. Mocker, 82 pages.

Over the last thirteen years, the world saw an increased use of improvised explosive devices (IEDs) by violent extremists and terrorist groups. Due to the simplicity and availability of IED making material, any willing person with limited knowledge can make IEDs. Given that the surface of the earth is eighty percent water, the maritime environment is a likely threat domain for terrorist activities. Navy Explosive Ordnance Disposal (EOD) has the sole capability in the Department of Defense (DOD) for countering the maritime improvised explosive device (MIED) tactical threat to United States national interests and security. EOD divers, with limited equipment, are still the primary resource to render safe the waterborne explosive threat. The wars in Iraq and Afghanistan proved that robotics and unmanned tools are essential to EOD operations ashore for safety and standoff from IEDs. Unfortunately, use of robotics in the maritime environment for EOD operations is relatively new and unproven. The primary thesis question is: "How can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment?" This thesis identifies a capability gap in safely countering MIEDs and recommends a materiel solution in closing the gap.

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ACRONYMS

AQD	Additional Qualification Designation
CI	Critical Infrastructure
C-IED	Counter-Improvised Explosive Device
C-MIED	Counter-Maritime Improvised Explosive Device
COTS	Commercial Off The Shelf
CRF	Coastal Riverine Force
DHS	Department of Homeland Security
DOD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership, Personnel, Facilities
EOD	Explosive Ordnance Disposal
IED	Improvised Explosive Device
JIEDDO	Joint Improvised Explosive Device Defeat Organization
KR	Key Resources
LTTE	Tigers of Tamil Eelam
MCM	Mine Countermeasures
MIED	Maritime Improvised Explosive Device
MMS	Marine Mammal System
MOTR	Maritime Operational Threat Response
NATO	North Atlantic Treaty Organization
POE	Potential Operational Environment
ROC	Required Operational Capabilities
ROV	Remotely Operated Vehicle

RSP	Render Safe Procedure
SIPRNet	Secret Internet Protocol Router Network
SLOC	Sea Lines of Communication
TTP	Tactics, Techniques, and Procedures
TVL	TV Lines
UUV	Unmanned Underwater Vehicle
VBSS	Visit, Board, Search, and Seizure
WBIED	Waterborne IED

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CHAPTER 1

INTRODUCTION

> Now an army may be likened to water, for just as flowing water avoids the heights and hastens to the lowlands, so an army avoids strength and strikes weakness. And as water shapes its flow in accordance with the ground, so an army manages its victory in accordance with the situation of the enemy. And as water has no constant conditions. Thus, one able to gain the victory by modifying his tactics in accordance with the enemy situation may be said to be divine.
>
> — Sun Tzu, *The Art of War*

Maritime Improvised Explosive Devices: A Maritime Threat

As the United States continues its global war on terrorism, one area of the threat domain that is often overlooked is the maritime domain. "Terrorism at sea represents only two percent of all terror attacks in the past 30 years" (Martin 2010, 2). Just like terrorism on land, there are numerous ways to inflict terrorism at sea, such as piracy and maritime improvised explosive devices (MIED). "MIEDs can take many forms, which can include floating improvised mines, home-made submersibles and semi-submersibles, free swimmers/divers, small radio-controlled or manned boats packed with explosives, and booby traps on vessels subject to visit, board, search, and seizure (VBSS) operations" (NATO 2014). Ninety percent of world trade is accomplished through the oceans, seas, bays, estuaries, islands, coastal areas, littorals, and the airspace above them (U.S. Navy 2007, 5).

The Department of Homeland Security (DHS) has recognized capability gaps in research and innovation to counter MIEDs. Dr. Ruth Doherty documented that for MIEDs a "desired technology will provide capabilities to detect, diagnose, and disrupt or disable IEDs by remote, semi-remote, or manual means in a maritime environment.

Technology must address IEDs attached to ship hulls at depth and devices attached to small crafts afloat that may be used themselves as explosive devices" (Doherty 2009).

Current TTPs place the EOD diver in the water with the improvised explosives in a situation where proximity to a detonation would have an extremely high likelihood of being deadly. Conversely, when countering land-based IEDs, EOD technicians are provided protection and standoff by using bomb suits, robots, and the characteristics of surrounding terrain. EOD technicians often use cover to protect themselves, taking advantage of cover to provide blast attenuation. Cover is a physical barrier such as a hole, tree, or building that can separate one from the effects of blast or fragments. During an IED detonation on land, the shock wave from the blast immediately disperses into the atmosphere, and is attenuated by the compressible nature of the gaseous atmosphere. On the contrary, a MIED detonation at depth produces a shock wave that travels farther and faster with higher pressure than the shock wave through air due to the incompressibility of water (Military Intelligence Service 1944, 83). Another factor is the initial "gas bubble" formed from the shock wave that collapses once its pressure drops below the hydrostatic pressure at depth and then expands again creating a series of "gas bubbles" and shock waves. The result is a large plume of water as the gas bubbles reach and break the surface tension. An EOD diver could be exposed to the underwater shock wave while attempting to disarm a MIED (Sulfredge, Morris, and Sanders 2005, 1). A bomb suit is designed to protect a technician from the effects of blast and fragmentation. While the conventional bomb suit is effective on land and used in conjunction with cover, there is currently no floating maritime bomb suit that can attenuate the shock wave from a blast of an underwater detonation, and the vast open maritime terrain provides no cover. EOD

divers in the maritime environment do not have the luxury of bomb suits or intervening terrain. A maritime bomb suit could potentially be developed for underwater EOD operations. The Navy could also designate Marine Mammal Systems, such as dolphins, that are already used for mine countermeasure (MCM) operations to detect, locate, and neutralize MIEDs. Additionally, robots appear to provide the desired increase in standoff distance from a device for the EOD technician.

One of the most historical and significant MIED incidents to affect the U.S. military was the bombing of the USS Cole in 2000 in Yemen. The MIED was a small fiberglass boat packed with approximately two hundred and fifty pounds of explosives and two suicide extremists. The result was devastating, but was also an awakening to the growing potential threat to U.S. interests. The MIED threat does not only exist overseas; domestic terrorists have also utilized MIEDs. In 2004, authorities found and neutralized a floating bag in Lake Pontchartrain, Louisiana, with two to three pounds of explosives in a waterproofed plastic pipe with a timer system. The attack was a deliberate domestic maritime act of violence or terrorism (Martin 2010, 18).

Research Question

In the last thirteen years, the world saw an increased use of IEDs by violent extremists and terrorist groups. Due to the simplicity and availability of IED-making material, any willing person with limited prior knowledge can make IEDs. Given that the surface of the earth is 80 percent water, the maritime environment is a likely threat domain for terrorist activities. Navy EOD has the sole capability in the Department of Defense (DOD) for countering the MIED tactical threat to the United States' national interests and security. EOD divers, with limited equipment, are still the primary resource

to render safe the waterborne explosive threat. The wars in Iraq and Afghanistan proved that robotics and unmanned tools are essential to EOD operations ashore for safety and standoff from IEDs. Unfortunately, use of robotics in the maritime environment for EOD operations is relatively new and unproven. The primary thesis question is how can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment?

Several subordinate research questions based on a doctrine, organization, training, and materiel (DOTM) framework that will assist in analyzing the topic in more depth and identifying capability gaps in the ability to respond to and counter MIEDs safely are:

1. What is the capability gap in the U.S. Navy's existing ability to counter MIEDs?
2. Doctrine: What government and international agencies will the Navy need to work with to counter MIEDs nationally and globally?
3. Organization: What military units can EOD cross train with to close a capability gap?
4. Training: How could Navy EOD adjust TTP to counter the MIED threat more safely?
5. Materiel: What materiel solutions could provide the capabilities needed for countering the MIED threat?

Personal Qualifications

As a Navy EOD Officer, I have had a variety of experiences and training opportunities to afford me working knowledge of IEDs and underwater explosives. As a newly commissioned officer, I attended Naval Dive and Salvage Training Center, and

learned dive and salvage techniques applicable to MIEDs, and underwater physics. I served eighteen months on a Mine Counter Measures ship, earning a Surface Warfare qualification, gaining an understanding in conventional counter-mine equipment and TTPs. I had the opportunity to work first hand with the AN-SLQ 48 Mine Neutralization Vehicle, a large remotely operated vehicle (ROV) used to locate, identify, and neutralize underwater mines.

In 2007, I completed Explosive Ordnance Disposal School with in-depth understanding of improvised explosive devices, and five weeks of underwater mine exploitation and render safe techniques. I deployed twice to Iraq, conducting EOD and counter-IED operations. This provided a deeper understanding of the IED network and proliferation. In 2012, I completed the Basic Mine Counter Measure course, earning the BN1 additional qualification designation (AQD). BN1 is a code that identifies a qualification, skill, and knowledge outside of my primary job functions. I served six years in the PACOM theater of operation, which provided my first exposure to and insight into the use of MIEDs and their vast impact on maritime operations. From 2010-2012, I was the Officer-in-Charge of an EOD shore detachment in Japan, which was responsible for providing EOD response for the U.S. Navy in Japan. I was exposed to the Seabotix UUV for conducting hull searches of ships and general underwater searches. From 2012 to 2014, I served as the EOD liaison to the Commander, Task Force 70 (Carrier Strike Group, FIVE) advising on all EOD and IED related issues.

Although I have never responded to an actual MIED, I have had training and operational exposure to current TTPs and a variety of equipment used by EOD technicians. My firsthand knowledge provides insight one could not gain through

secondary research. This series of sequential and progressive experiences caused me to ask, "Why have we not applied the lessons learned in dealing with IEDs on land to the maritime environment? Specifically, why don't we have analogous equipment that is appropriate for the maritime environment?" Rather than simply conclude, "we need a robot" and justify that conclusion, I chose to approach the issue as a research problem, in order to consider a number of possible solutions, using a modified DOTMLPF framework. This broader spectrum approach is a deliberate attempt to counteract potential researcher bias. Other efforts to mitigate researcher bias will be described elsewhere.

Assumptions

This research is based on several key assumptions, which will act as constants. Assumptions in this case are items out of the control of this research project, but if not assumed, the research will be irrelevant or inconclusive. The following assumptions will be considered as facts for the remainder of the thesis. The first assumption is that MIEDs will continue to be a threat and attacks will increase in extent of use and frequency of occurrence. Today, MIEDs are not a constant, everyday threat, but their potential exists, making this research practical and necessary. A second assumption is the MIED is both an asymmetric undersea weapon and an employment technique used to disrupt domestic and international waterways. This assumption points toward a need for interagency coordination between DOD and DHS.

Terms and Definitions

Terms used in this thesis are described below.

Counter-Improvised Explosive Device (C-IED). A comprehensive approach of countering the threat networks that employ Improvised Explosive Devices (IEDs), defeating the devices themselves, and training others.

DOTMLPF. A DOD process that provides for solutions involving any combination of doctrine, organization, training, materiel, leadership and education, personnel and facilities.

Department of Defense. The department of the U.S. federal government charged with ensuring that the U.S. military capacity is adequate to safeguard national security.

Department of Homeland Security. The department of the U.S. Federal government charged with protecting U.S. territory from terrorist attacks and providing a coordinated response to large-scale emergencies.

Explosive Ordnance Disposal (EOD). The detection, identification, on-site evaluation, rendering safe, recovery, and final disposal of unexploded explosive ordnance. It may also include explosive ordnance which has become hazardous by damage or deterioration.

Improvised Explosive Device (IED). A homemade bomb constructed and deployed in ways other than in conventional military action. It may be constructed of conventional military explosives, such as an unfired artillery round attached to a detonating mechanism, or incorporate homemade explosives as the main charge.

Marine Mammal System (MMS). Program administered by the Navy, which studies the use of marine mammal for military purposes. For this thesis, it will refer to mammals trained and used for mine countermeasures.

Maritime Improvised Explosive Device (MIED). Floating improvised mines, home-made submersibles and semi-submersibles, free swimmers/divers, small radio-controlled or manned boats packed with explosives, and booby traps on vessels subject to visit, board, search, and seizure (VBSS) operations (NATO 2014); also known as Waterborne IED (WBIED).

Mine Countermeasures (MCM). All methods for preventing or reducing damage or danger from undersea mines.

Remotely Operated Vehicle (ROV). Tethered underwater vehicle that is controlled and powered from the surface.

Render Safe Procedure (RSP). The portion of the explosive ordnance disposal procedures involving the application of special procedures, methods and tools to provide the interruption of functions or separation of essential components of unexploded ordnance (including improvised explosive devices) to prevent an unacceptable detonation.

Sea Lines of Communication (SLOC). Term describing the primary maritime routes between ports used for trade, logistics, and naval forces.

Unmanned Underwater Vehicle (UUV). Underwater vehicle that operates independently of direct human input during normal operations. UUVs typically require human input before commencing operations, such as preprogramming a mission profile or preprogramming tasks to be completed.

Limitations

This research is limited to unclassified information. This limits the amount of information available for this thesis, as much of the current research and development is

classified to at least the secret level. Research is also limited to a qualitative review and qualitative assessment of previously established specifications due to the current lack of availability of bomb suits, marine mammal systems, and UUVs and ROVs for original testing and research.

Scope and Delimitations

This research is limited to the study of EOD counter-MIED operations. It will not assess actions and capabilities by other units such as shipboard force protection measures. It will also assume that the adversary personnel in small boat and suicide attacks have been neutralized prior to an EOD response, and the small boats are therefore equivalent to floating MIEDs. The research will only explore doctrine, organization, training, and materiel in the DOTMLPF analysis process. It will not include leadership, personnel, and facilities as these are already established and do not appear to be likely avenues for a capability gap closure. It is important to note this thesis will not cover the strategic or operational level organization of Navy EOD within the framework of DOTMLPF, because that organizational structure already exists, but will look at external organization linkages to support, augment, and enhance EOD operations. The structure, responsibilities, and capabilities of Navy EOD are discussed in *Naval Responsibilities for Explosive Ordnance Disposal Program and Mission Support* (U.S. Navy 2014b). Per this instruction, all EOD platoons are capable of conducting diving and demolition operations to include underwater clearance and riverine operations. It will also not assess the feasibility of procurement caused by funding availability for a materiel solution. If a materiel solution is determined to be the most suitable, the best solution will be recommended, regardless of potential cost.

Significance of Study

While other documents have widely acknowledged the MIED threat and the importance of countering the threat, this research intends to fill the gap between the strategic level and the tactical level. The intent is to provide a document that effectively conveys recommendations for Navy EOD leaders to make decisions on the future training, doctrine, organizational linkages, and equipment for EOD technicians to support counter-MIED operations.

The conclusions of this study will be available to the U.S. Navy Explosive Ordnance Disposal Technology Division. The results could be utilized to improve military procedures, effectiveness, and developments in countering the MIED threat. This study will focus on the need for and the required capabilities of a potential solution to countering MIEDs. It will look at doctrine, organization, training, and materiel for solutions to safely defeat the MIED threat. The goal is to identify any gaps and provide recommendations to allow for quicker and safer responses by EOD, potentially saving property and life.

Summary and Conclusion

As previously noted, maritime terrorism comprises less than 2 percent of all terrorist attacks (Martin 2010, 2). However, world trade would be significantly impacted if maritime violent extremism increased because 90 percent of world trade is transported through the maritime domain (U.S. Navy 2007, 5). Navy EOD has actively participated in countering the land IED threat over the last thirteen years, and is shifting its focus to countering the maritime threat. Because of this recent focus on participation in land warfare, there appears to be a gap in Navy EOD ability to counter IEDs in the maritime

domain. Lessons learned in tactics, capabilities, research, and development could be applied to developing a suitable maritime solution for searching, locating, rendering safe, and disposing MIEDs. Chapter 2 will provide insight to the history, policy, doctrine, and current and future technology for providing a secure maritime environment from the MIED.

CHAPTER 2

LITERATURE REVIEW

> Without mastery of the sea--without Sea Power--we cannot protect trade, we cannot help those in peril, we cannot provide relief from natural disaster, and we cannot intercede when whole societies are torn asunder by slavery, weapons of mass destruction, drugs, and piracy. Without sea power, we cannot hope--the world cannot hope--to achieve what President Bush has called "a balance of power" that favors freedom. (Tan 2010, 7)
>
> — Admiral Michael Mullen

> Damn the torpedoes, full speed ahead! (Duffy 2008, 248)
>
> — Admiral David Farragut

Organization

Chapter 2 is organized by the major themes that address the research questions. It first covers the literature that provides a historical context and current use of the MIED addressing the potential threat. It then covers the current policies and military doctrine in place to counter the maritime threat. Next, it discusses Navy EOD and the relevancy to the organization for conducting C-MIED operations. Then, it covers current capabilities of Navy EOD. Finally, it covers previous perceptions of a capability gap and potential capability gap solutions for IEDs in the maritime domain. This will provide the basis for answering the research question of "How can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment?"

Much of the literature concerning the thesis topic is concentrated on the process of countering MIEDs such as a systematic approach to countering the threat, vice the tactical level EOD capabilities required to counter the MIED itself. A research thesis by Systems Engineering Analysis Cohort 14 explored the topic to "design a system of

systems that rapidly and efficiently mitigates the effects of a Maritime IED or Maritime IED threat to the Maritime Transportation System while protecting critical infrastructure and key port assets" (Causee et al. 2008, xxiii). Their findings consisted of a need for "unmanned systems, computer aided decision-making, underwater data networks, and non-explosive neutralization techniques" to deal with the threat of the MIED (Causee et al. 2008, 147).

To understand fully the maritime threat, one has to look at the potential targets for violent extremists in the maritime domain. Reviewing and analyzing historical attacks will provide a useful background of past targets and the methods of attack, which may provide useful insight into possible future MIED uses. Critical maritime infrastructure may be the next target. Critical infrastructure can include oil platforms, ports, commercial shipping, and sea lines of communication (SLOC). This can be as simple as targeting global choke points such as the Straits of Hormuz (Chalk 2008).

There are several policy documents such as the *National Strategy for Maritime Security* and *A Cooperative Strategy for 21st Century Seapower* that discuss the vital importance of the maritime domain and several of the threats that exist, including the MIED (House 2005; U.S. Navy 2007). Literature and technical military documents are the primary source for research, to include Required Operational Capabilities and Potential Operational Environment (ROC & POE).

Background and Threat

Looking at the historical threat helps to gain an understanding of the nature of the potential threat, trends, and tendencies of terrorist groups that would use the MIED as a weapon of choice. Martin introduces the trend in attacks and proposes why terrorists tend

to stay away from the maritime environment. He makes several key points in his paper to include that maritime attacks usually produce less public reaction and perceived threat than a land-based target. Terrorists perceive land targets as more valuable than maritime targets. With a few exceptions, terrorist groups also tend to lack maritime skills such as operating boats and the engineering skills required to make MIEDs that will be successful in the harsh saltwater environment of the maritime domain (Martin 2010, 3).

Martin also analyzes specific groups that have had success in the maritime domain. Al Qaeda, Abu Sayyaf, a Philippine affiliate, and the Tigers of Tamil Eelam (LTTE) are considered experts in the maritime environment and provide the majority of historical examples of successful MIED attacks (Martin 2010, 6). While reviewing historical attacks, Martin also looks at the critical targets of choice by the aforementioned groups. A common theme among the targets of choice is infrastructure and commerce to include oil and gas platforms, bases, dams and locks, and container and oil tankers (Martin 2010, 7). As Martin observed, "these are the hubs of the global maritime economy" (Martin 2010, 7). A 2002 estimate addressing the closure of any main U.S. port from a maritime attack indicated such an attack could cost the economy in excess of $2 billion per day (Martin 2010, 18).

One tactic used by LTTE was the employment of improvised mines, a category of MIEDs. Martin makes the connection that there are similarities between the MIEDs used by LTTE and the ones used in the waters off the coast of Iraq in 2003 (Martin 2010, 17). Martin also discusses several attacks that were unsuccessful, mostly due to the capture of a key Al Qaeda maritime mastermind, Abd al-Rahim al-Nashiri, also known as "The Prince of the Sea" (Martin 2010, 10). When captured, he was reported as having a 180-

page dossier outlining future attacks using MIEDs and maritime targets of opportunity. The tactics described by al-Nashiri were to use small boats laden with explosives, underwater demolition teams to place explosives on the target, and the use of explosive-outfitted suicide swimmers. This was confirmed when two Abu Sayyaf operatives were captured, and exposed the terrorist group's interest in diver training and underwater navigation with no interest in learning decompression techniques and diver safety (Martin 2010, 21). This is similar to the hijackers of the 9-11 terrorist attacks. Flight school instructors recall several of the hijackers as poor students wanting to learn to fly jet aircraft immediately and learn only to control the aircraft. They did not have a desire to learn the intricacies of takeoffs and landings. This corresponds to learning decompressing in the diving world (National Commission on Terrorist Attacks 2004, 222). LTTE successfully used these tactics in the sinking of a merchant ship, MV Invincible, in May 2008. Part of a body and diving equipment were found among the wreckage (Martin 2010, 21).

Domestic maritime attacks are extremely possible considering the vast inland, coastal, and littoral waterways surrounding and within the U.S. One specific example Martin discusses is the Lake Pontchartrain, Louisiana incident of April 2004. A MIED containing two to three pounds of explosives in a waterproofed container was found floating in the lake just prior to a high profile political event. This device was noted for its simple, cheap construction but high potential for lethality (Martin 2010, 18).

Martin, in his conclusion, summarizes the ease of concealment of the MIED and the need to focus on the threat. The maritime environment offers soft targets, targets with limited self-defense measures that can easily be attacked, such as industrial facilities and

passenger liners. Inland targets are also vulnerable because of the ease of access and the numerous connections to maritime environments using the rivers and littorals (Martin 2010, 25).

Joint Improvised Explosive Device Defeat Organization (JIEDDO) completed an assessment titled "Water-borne IED Threats and the Strait of Hormuz" which focusses on the Strait of Hormuz as a strategic chokepoint (Tomasi 2009). JIEDDO looked at the threat of groups or nations disrupting global trade. As mentioned in Martin's writings, JIEDDO reports that al Qaeda has been planning maritime attacks focusing on chokepoints (Tomasi 2009, 1). Unsuccessful al Qaeda attacks included plots against the Strait of Gibraltar and the Suez Canal (Tomasi 2009, 4). These tactics are similar to that employed by LTTE (Tomasi 2009, 1). While this document focused on the Strait of Hormuz because of the strategic location and impact to shipping and oil commerce in the Middle East, it is realistic to assume attacks of this nature could occur at locations within or closer to the United States.

In 2004, a suicide WBIED attack occurred when a boarding team from the USS Firebolt was boarding a fishing boat at the Al Amaya Oil Terminal off the coast of Iraq. The WBIED suicide bomber detonated the device killing several members of the boarding team (Tomasi 2009, 2). The JIEDDO assessment also described al Qaeda's "Prince of the Sea" and corroborated the use of MIEDs and suicide divers utilized by al Qaeda to target maritime vulnerabilities. Tomasi also discussed the relationship between LTTE and al Qaeda and the similarities in attacks. LTTE executed ten successful MIED attacks in Sri Lanka using small boats laden with explosives (Tomasi 2009, 3). This is considered an asymmetric maritime attack and method for delivering MIEDs.

While not focusing extensively on the historical attacks, Peter Chalk discusses the threat of maritime security in his RAND Corporation monograph, *The Maritime Dimension of International Security* (Chalk 2008). He begins by explaining the potential shift for terrorist activities in the maritime environment. He provides five reasons for possible increases in terrorist attacks: increased vulnerabilities, growth of commercial enterprises, ease of causing mass economic destabilization, means of inflicting mass, coercive punishment, and the global facilitation of container shipping (Chalk 2008, xiii).

Both Chalk and Martin looked at the lack of mariner skills of terrorist organizations as a reason why MIEDs are not as prevalent as land-based attacks. Chalk suggests this is because many terrorist organizations are neither located near the coast nor possess the physical reach (Chalk 2008, 19). Terrorist groups would need to possess the material assets and the will to operate in the maritime environment. Chalk suggests that their will to learn to operate in the maritime environment is directly related to the cost and unpredictability of the maritime realm (Chalk 2008, 20). He states that "jihadist networks are moving to decisively extend operational mandates beyond the purely land-based theaters" (Chalk 2008, 21).

> It is also worth bearing in mind that maritime terrorism, to the extent that it does have at least as residual disruptive economic potential, resonates with the underlying operational and ideological rationale of al Qaeda and the wider global jihadist "nebula." Indeed, attacking the key pillars of the Western commercial, trading, and energy system is a theme that, at least rhetorically, has become increasingly prominent in the years since 9-11, and that is viewed as integral to the Islamist war on the United States and its major allies. (Chalk 2008, 24)

Chalk recognizes how maritime attacks will disrupt the global maritime environment, and are nested with the overall terrorist end state for waging war against the West. Recognizing and addressing the maritime terrorist threat is relevant to the U.S.

because 95 percent of non-North American trade by weight and 75 percent by value are transported through the maritime domain (Chalk 2008, 35).

Truver looks at the nontraditional and asymmetric threats and challenges faced by the U.S. and the DHS. He describes MIEDs as a true “sleeper threat” that can have a significant impact on U.S. maritime interests. He states, “If left unaddressed, they could constitute an Achilles heel for the U.S. homeland security” (Truver 2008, 1).

The employment of MIEDs in America is not a recent development. During the revolutionary war, American revolutionists attempted to place limpet mines on British flagships. This early MIED failed because of the protection provided by the iron fittings on the ships. Another failed MIED attack was the use of floating gunpowder kegs with contact-firing devices in the Delaware River against British ships. This early rudimentary form of a MIED did not make it to its intended target but demonstrated the employment of a new TTP. While retrieving the unknown device, four British sailors were killed. This early example of British EOD technicians employed similar manual procedures as contemporary response techniques (Truver 2008, 2).

Truver also acknowledged the ease and low cost of acquiring and making IEDs. These devices cost as little as tens of dollars to produce, but can have economic implications in the billions of dollars (Truver 2008, 2). The inexpensive construction, using fiberglass and plastic materials, make detection, identification, and countering difficult once the devices are placed in the water (Truver 2008, 3). During the Vietnam conflict, the Vietnamese used MIEDs and antipersonnel floating basket booby traps to attack ships and personnel (Truver 2008, 3).

In Cohort 14's analysis of MIEDs in U.S. ports, the threat and background of the MIED were discussed, and MIEDs were described as the "ideal asymmetric naval weapon" (Causee et al. 2008, 6). Cohort 14's thesis recognized that while MIEDs are the least expensive to produce they yield a great potential to be destructive, hence a weapon of choice. The U.S. has major hubs of domestic shipping that are ideal for terrorist maritime attacks. In 2008, Osama Bin Laden called for "chokepoint terrorism," which is likely to include attacks on U.S. shipping channels and ports as well as global chokepoints (Causee et al. 2008, 6).

Commander Jeremy Thompson, U.S. Navy, states the purpose of the MIED is to "destroy, incapacitate, harass, divert, or distract targets such as ships, maritime critical infrastructure and key resources (CI/KR), and personnel" (Thompson 2013). He also recognizes their use for area denial.

"Underwater improvised explosive devices are a credible threat," said Rear Admiral John Christenson, Vice commander of Naval Mine and Anti-Submarine Command, (Jean 2008). Jean discusses how the MIED is the number one terrorist threat the Coast Guard has to face. Not all military and political leaders agree on the threat assessment of the MIED. Truver stresses the importance of developments in the field of the MIED threat by saying, "if we don't plan for it, if we don't think about it in advance, just like the reactions since 9-11 in airport security, we're going to spend billions of dollars, most of it unwisely, with uncertain outcomes" (Jean 2008).

Policy

Another aspect this thesis examines is the coordination between agencies during a MIED attack. DOD is the agency that holds a majority of the trained assets for countering

MIEDs, such as Navy EOD. As Truver describes, the DHS and specifically the Coast Guard is responsible for domestic responses to MIED under the Maritime Transportation Security Act (Truver 2008, 5). Truver summarizes the complexity of interagency coordination:

> Under the 2005 *National Strategy for Maritime Security*, the *National Response Plan*, the National Incident Management System and the National Incident Command system, and the *Maritime Operational Threat Response* (MOTR) Plan provide the going-in architecture for Maritime Homeland Security operations. But regional, state, local, and commercial partners must also be closely integrated and informed, Indeed, a multiagency, multiple-governmental command, control, communications, intelligence, reconnaissance, and surveillance architecture and response system is needed for each U.S. port-or at least the seventeen "tier one" facilities having significant military or economic importance-within the overall maritime homeland security and maritime domain awareness framework. (Truver 2008, 5)

To help address some of the complexities, a memorandum of agreement was signed in 2005 between the DOD and the DHS. The agreement outlines command, control, and support for Maritime Homeland Defense, giving the Coast Guard tactical control over DOD forces (Truver 2008, 6). Control of Navy EOD forces would be turned over to the Coast Guard for domestic MIED responses. The most current *Joint Publication 3-27 Homeland Defense* outlines the command and control structure based on the memorandum of agreement. It states that the "Coast Guard may exercise tactical control over the capabilities or the forces of agencies, to include the DOD" (DOD 2013, II-18). This allows the Navy to operate under the control of the Coast Guard for domestic counter terrorism operations. The *Navy Operations Concept 2010* reinforces the *Maritime Operational Threat Response Plan* and the priority to coordinate with the Coast Guard for maritime security and maritime responses (U.S. Navy 2010).

Commander Laura Thompson emphasizes the need to embrace collaboration. The Security and Accountability for Every Port Act of 2006 mandated the DHS to establish interagency coordination, which includes the DOD (Thompson 2011, 30). One focus is establishing a Joint Interagency Task Force made up of key personnel from the various agencies with concerns in the maritime domain. Thompson recognizes the vulnerabilities of the maritime domain and the complexities of the operating environment. She states "collaboration and interoperability are key to resolving the weaknesses in the current U.S. maritime security framework" (Thompson 2011, 37).

Jean discusses how the Coast Guard does not intend to have its own countermeasure team for underwater explosive threats. Commander Thomas Atkin of the Coast Guard recognizes that the Navy has adequate EOD capability, and there is no need for redundancy in the Coast Guard. He also said, "What we need to do is to support the Navy here by growing the capacity to support our waterways" (Jean 2008). Rear Admiral Christenson agreed and stated that coordination and war-gaming between the Coast Guard and Navy is already taking place (Jean 2008).

U.S. Navy EOD Mission

Navy EOD response missions to MIEDs cover several tasks: detect/locate, access, identify/diagnose, render safe/neutralize, recover, exploit, and dispose. *Naval Responsibilities for Explosive Ordnance Disposal Program and Mission Support: OPNAVINST 8027.1H* states Navy EOD's mission is "to provide direct combat support to joint forces, enable access to areas denied by explosive ordnance, and to facilitate operational mobility and battle space maneuver" (U.S. Navy 2014b, 2). Another aspect of the EOD mission is to conduct research, development, test, and evaluation of new and

changing technology within the EOD warfare to enhance the EOD technician's capability. This factor is important to this thesis, because the responsibility falls on the EOD community to develop the required equipment capability to carry out its mission. *OPNAVINST 8027.1H* also outlines Navy EOD responsibilities when responding to assist non-DOD and federal agencies when requested and the requesting agency cannot provide timely EOD response capabilities of their own.

In the joint EOD environment, Navy EOD is the sole service with underwater capabilities and responsibility. *EOD Multi-service Tactics, Techniques, and Procedures for Explosive Ordnance Disposal in a Joint Environment* states the mission is to "support national security strategy by providing forces capable of conducting land and underwater detection, identification, render safe, recovery, filed evaluation, and disposal of explosive ordnance (Air Land Sea Application Center 2011, V-1). The term "underwater" includes the oceans and contiguous waters, high water mark of harbors, rivers, and coastal environments.

U.S. Navy EOD Current Technology

Any development in equipment, tactics, techniques, and procedures is a dynamic process. This would continue to be true in an effort to counter the asymmetric threat of the MIED. A piece of equipment every EOD team utilizes and trains with is the bomb suit. It is designed to protect a technician from blast overpressure, fragmentation, impact, and heat. This is achieved through a full body suit made up of Kevlar and armor plating with significant protection in the front. A negative side effect for all the protection the suit provides is the significant weight, which is approximately fifty-six pounds. There is some degree of flexibility and comfort in the design. The bomb suit has been tested

against twenty kilograms of explosives at a distance of three meters. This provides significant blast overpressure protection for a technician manually disarming an IED (Vanguard). Currently there are no floating or maritime bomb suits to protect EOD technicians approaching a MIED. Taking an approach that applies what was learned in Iraq and Afghanistan, there appears to be a potential use for a suit that protects on land and also on the water. It would need to provide the same level of protection but also the ability to float on the surface and dive to depth. The suit would need to protect against the shock wave and "gas bubble" caused by an underwater detonation of a MIED (Sulfredge, Morris, and Sanders 2005, 1).

While not specifically used for MIEDs, the Navy has a marine mammal program that utilizes the Marine Mammal System (MMS) as a tool for locating and marking naval mines. Since the principle for detection and marking an MIED would be similar to that used in mine warfare, MMS trained for mine warfare could be retasked and trained to operate in an environment with MIEDs. The Navy uses dolphins and sea lions for their keen sensor and diving capabilities. Dolphins have the ability to sense and detect underwater items at a far greater distance and depth than current human capabilities, which is especially useful in the vast areas of the open ocean or the murky coastal waters and ports. Marine mammals can make repeated deep-water dives without the need to decompress to avoid suffering the effects of decompression sickness. "One sea lion, two handlers, and a rubber boat searching for objects on the ocean floor can effectively replace a full-sized naval vessel and its crew, a group of human divers, and the doctors and machinery necessary to support the divers operating onboard the vessel" (U.S. Navy 2015a).

The Navy currently has the MK 4, MK 7, and MK 8 mammal mine detection systems. During operations, the mammal will search for explosive devices, in this case mines, in a specified location. Once something is found, the MMS reports back to its handler. The mammal marks the explosive threat in order to allow Navy EOD divers to return to its location and handle the object appropriately. Even though MMSs are used to locate and mark the explosive device a human diver is still required to neutralize, render safe, and/or exploit the device. MMS deployed to the North Arabian Gulf in 2003 for Operation Iraqi Freedom and were instrumental in clearing the port of Umm Qasr (Boyle 2003).

Although these systems have proven useful in the most recent wars, the Navy is currently scheduled to start phasing out the MMS in 2017. The reason is not because of ineffectiveness or based on the lack of a threat. The driving factor is cost and the time to train the dolphins. MMS can take up to seven years to train (Guardian 2012). The cost of a MMS includes transportation to the working area, food, custom built transportation and training facilities, and lifetime care well after retirement of the MMS. The Navy is looking at robots to fill the void in the vital searching capabilities of mammals. Captain Frank Linkous, head of the Navy's Mine Warfare Branch, said that "the sea mammals are a "fantastic system," but robotic technology will be able to do much of what they can do only cheaper and easier" (Weinberger 2012).

Currently, the Navy is also looking at robotics to assist EOD technicians while responding to maritime threats, including MIEDs. A key DOD document, only available in draft form, *Robotic Solutions for Navy EOD Response to Maritime Explosive-laden Threat Incidents: A Roadmap for Fielding and Sustaining Enhanced Response*

Capabilities, discusses a perceived materiel solution to a capability gap in conducting C-MIED operations. The premise for the DOD document is to address a robotic materiel solution for combating maritime explosive threats using an approach similar to the solutions for land responses to IEDs. It states, “Navy EOD forces are aligned, manned, equipped and trained to perform the response mission once underwater explosive threats have been detected and localized by other search assets. Whether this function is performed by ROVs, by divers, or by the tactical integration of the two, the basic underwater explosives “engage” tasks rest with the Navy EOD force” (U.S. Navy 2014a, 16).

Currently, Navy EOD is using commercial off the shelf (COTS) equipment to fulfill the UUV requirement. The UUVs designed and in place since 2003 are mainly for searching and detecting maritime threats. They do not provide the full range of response capabilities required in today’s environment. The primary render safe task still relies on the manual approach of EOD divers (U.S. Navy 2014a, 3). The robotics currently available to the operational force are not sufficient for use when neutralization or render safe is required and high order detonations are not acceptable (U.S. Navy 2014a, 8). These UUV assets are also limited in inventory and do not have the robust support structure in place for life cycle maintenance and supplies (U.S. Navy 2014a, 7).

The Perceived Capability Gap and Potential Solutions

Thompson concludes that a capability gap exists when facing the challenge of countering MIEDs. Currently, a human must expose himself to the often-unknown hazards of the MIED (Thompson 2013). As Jean states, “the IEDs could be emplaced surreptitiously and remotely detonated or automatically activated” (Jean 2008). The draft

EOD robotic solutions document emphasizes the essential role of robotics in safely countering maritime explosive threats including the MIED. Use of robots can minimize the time a diver will spend in the water with the explosive threat, provide standoff distance between a device and humans responders, and minimize the time on target for both divers and technicians on the surface (U.S. Navy 2014a, 1). The Commander of the Navy Expeditionary Combat Command, in charge of the U.S. Navy EOD force, has stressed the importance of robotics in recent planning, programming, and budgeting system submissions (U.S. Navy 2014a, 11).

The Navy's robotic solutions document clearly identifies that the "Navy EOD force has recently identified the transition to robotic solutions as a high priority, motivated largely from the lessons learned in countering improvised explosive device threats in the land wars of the past decade" (U.S. Navy 2014a, 10). Thompson acknowledges the importance of the lessons learned by stating that maritime robotic solutions should look, feel, and respond similar to the robots used on land. He highlights the characteristics of the TALON by QinetiQ and Packbot by iRobot. He also recommends that the DOTMLPF assessment take the most likely and most dangerous type attack, a hull attack or floating MIED, into consideration. His recommendations include incorporating input from civilian bomb squads during design and development of a robotic solution to enable valuable coordination and program cost reduction (Thompson 2013).

U.S. Navy EOD Robotic Future

Martin recognizes the potential threat of MIEDs and suggests, "Non-human disposal is the best option, utilizing vessels such as the Talisman Underwater Vehicle"

(Martin 2010, 20). Many Navy professionals agree there is a threat of MIED and that robotic solutions are essential, based on experience in the last ten years of war, but what exactly will be the capabilities and function of an ROV or UUV in countering this threat? The Navy EOD community has been discussing this topic for several years.

MIEDs can be employed in a wide range of operating environments, from surface floating devices to emplacement on ship hulls, areas around piers, pilings, and other underwater structures (U.S. Navy 2014a, iv). These are generally areas with poor conditions, including low to no light, high turbidity, and significant marine growth, which can negatively affect a diver and a UUV's capability to respond efficiently (U.S. Navy 2014a, 15). Other characteristics of the operational environment that affect divers and UUVs are sea state, surge, current, thermoclines, and buoyancy (U.S. Navy 2014a, A-4). UUVs and Navy EOD will enable increased port security, harbor defense, and clearance operations (U.S. Navy 2014a, 4). An efficient robotic solution will need to operate in all these environments.

The Chief of Naval Operations validated an Initial Capabilities Document based on a comprehensive Joint Capabilities Integration and Development System analysis for a robotic solution for an EOD response capability to maritime explosive threats (U.S. Navy 2014a, 9). Based on a DOTMLPF solution, the Initial Capabilities Document states that "all materiel solutions ultimately selected for fielding must address the operational and functional EOD boundary conditions of transportability and portability, small unit employment concepts, ease of use, minimal logistics footprint, high reliability and operations in harsh environmental conditions" (U.S. Navy 2014a, 9). The draft roadmap also suggests a capability gap created by current UUVs because of their limited scope of

use beyond that of search and locating functions for countering MIEDs and explosive threats (U.S. Navy 2014a, 10).

Commander Thomas Reynolds suggests a gap exists in training and focus of the EOD teams. He states, “our EOD teams have spent the past several years supporting the Army and Marine Corps in intense combat ashore and need to refocus on underwater tactics” (Reynolds 2013, 55). He does however recognize the similarities in the MIED and roadside IED experienced in the last 12 years. Commander Reynolds advocates that the “best-known innovation by our counter-IED forces in Afghanistan and Iraq has been to introduce the wide use of small, mobile robots to defuse roadside bombs, significantly reducing the risk for EOD technicians” (Reynolds 2013, 55). He also suggests that since the technology, platforms, and organizations already exist, a maritime version of the robots successful on land can and should be replicated.

In the draft EOD document, potential operational environments and initial capabilities are discussed, as well as what operational robotic capabilities will be required. A robotic solution will need to be man portable and have a high agility while operating in close proximity to the explosive (U.S. Navy 2014a, C-2). A man portable characteristic facilitates the performance of small EOD teams, which operate from as little as two to eight-man teams. While working on a MIED the least amount of personnel inside the blast radius the better. Along with agility, maneuverability and a dexterous manipulator is desired (U.S. Navy 2014a, C3). In general, robotic solutions will need to cover the range of operations from locate/detect to render safe and disposal (U.S. Navy 2014a, 6).

Navy EOD is not the only organization looking at robotic solutions to counter the MIED threat. DHS recently announced a contract for the development of ROVs for the MIED threat. Saab will be developing a robot for the Department's Underwater Hazardous Device Team. Agneta Kammeby, head of Saab's Underwater Systems business unit, stated, "This is a significant challenge, but de-risking the maritime IED threat is an essential task" (Tomkins 2014).

Summary and Conclusion

In summary, the background and historical data addressing MIEDs describe a viable maritime threat. Policy documents of the DOD and the DHS recognize MIEDs as a threat and the importance of developing security measures to counter the threat. Part of countering a threat is the coordination effort between different agencies. Command and control agreements exist to expedite DOD and DHS response capabilities. The Navy doctrine reviewed develops an understanding of the nature of Navy EOD responses to explosive threats in the maritime environment and establishes their sole responsibility for maritime EOD capabilities. While bomb suits, MMSs, and UUVs do exist, there is a wide variety of capability gaps in each of their performance. Current assets do not have the capabilities to cover the full range of missions required by EOD units in order to completely and safely respond to the MIED threat. The diverse environment and range of MIEDs makes the development of a new maritime EOD response capability a high priority goal in order to protect human lives. As the EOD community looks ahead to developing such a capability, lessons from the fourteen years of combat in Iraq and Afghanistan help set the framework for capabilities and development of a maritime bomb suit, MIED specific MMS, or maritime robot.

Literature discusses the threat, identifies a capability gap, and suggests a need for a solution to the threat of IEDs. This thesis focuses on potential materiel solutions from the perspective of the EOD technician and the required MIED response capabilities, which are similar to the response techniques for roadside IEDs. It will focus on the range of operations while conducting C-MIED operations to include locating, identification, neutralization, RSP, and disposal. It will also explore additional units and assets that could be used to enhance response capabilities of EOD forces.

CHAPTER 3

RESEARCH METHODOLOGY

> If a ship has been sunk, I can't bring it up. If it is going to be sunk, I can't stop it. I can use my time much better working on tomorrow's problem than by fretting about yesterday's. Besides, if I let those things get me, I wouldn't last long. (Carnegie and Kiley 1948, 6)
>
> — Admiral Ernest J. King

Admiral King's focus on solving future problems drives the point of this research. The past cannot be changed, but the future can be shaped by what is done in the current environment. It is about using information to solve complicated problems for a greater good.

Method

Chapter 3 addresses the methodology used for studying the primary research question of how the Navy could address the MIED threat in the contemporary operating environment. The focus is on a capability gap and potential materiel solutions to include maritime bomb suit, MMS, and robotics. This chapter will first discuss the principle behind using a qualitative approach, and why it was chosen for this research study. It will then discuss the specifics in more detail for this thesis, and how research was conducted. It will also describe the framework used in the analysis and interpretation in chapter 4.

The overarching research approach applied throughout this thesis is a sequential qualitative–qualitative–quantitative method, from a primarily postmodern perspective. A postmodern perspective acknowledges the fact that the research is premised on the understanding and interpretation of the researcher. It takes a skeptical approach to other research and explanations, which claim to be valid and universal truths. The advantage of

a postmodern perspective with a qualitative approach lies in the interpretation of the research presented. It relies on interpretation of the MIED threat, identifying a possible capability gap to counter the threat. The postmodern approach allows the researcher to dismantle normal ways of thinking, and distance oneself from an approach with one absolute solution.

A qualitative approach is being used because of the ability to turn narrative description and difficult, or impossible to quantify, information into meaningful data. Cresswell describes the qualitative approach as one in which the researcher collects "open-ended, emerging data with the primary intent of developing themes from the data" (Cresswell 2003, 18). He also acknowledges the qualitative approach is best used for a new topic that has limited prior research or understanding of the topic. This allows the researcher more room for interpretation and innovation (Cresswell 2003, 22).

This research will not present new data, but will provide a new perspective on data collected, reviewing data and material previously studied and discussed by others. Because of these factors, this research utilizes a mixed qualitative and quantitative method, which allows for a greater understanding of the research question through data interpretation. Individual interpretation and evaluation of these documents are essential to the research conclusions provided in chapter 5.

Defining the Problem

The first step in conducting research is selecting a problem and a sense of purpose for the research. As Wolcott stated, "a researcher lacking a clear sense of purpose–the ability to set a problem–cannot narrow the research focus sufficiently to achieve any purpose at all" (Wolcott 1994, 402). The problem and research question was refined to

answer, “How can Navy EOD counter the MIED threat in the contemporary maritime environment?” Originally, this research focused broadly on the MIED as a threat and the general TTPs to counter the threat. The revised focus for this thesis is to examine the threat of the MIED and to develop an understanding of the potential dangers of conducting C-MIED operations in the current maritime domain. The scope of the thesis was further narrowed to identifying a capability gap in C-MIED operations and the potential for a solution to close the gap when countering the MIED threat.

Data Collection

After the purpose and problem are selected, the next research step is to focus on data collection, which is defined as gathering evidence to sift through, sort, and evaluate while maintaining skepticism towards everything one hears about the topic (Wolcott 1994, 22). One approach to data collection, suggested by Wolcott, is using a process of thinking “finish-to-start,” and emphasizing how you plan to use the data and not the specifics of the data itself (Wolcott 1994, 404). This approach allows the researcher to think about the interpretation and analysis they intend to make, and helps focus where to collect the data, and what type of data is required to answer the research question. The research conducted for this thesis took the “finish-to-start” approach. Simply stated, while collecting data, the researcher focuses on the research question, problem, and solution. Specifically, this research assumes there is a MIED threat, which implies Navy EOD has to counter the threat. The data collected, analyzed, and interpreted should support or denounce this research assumption. Thinking about the “finish” allows the researcher to keep a broader perspective while answering the research question.

Research was predominately a documentation review comprised of internal Navy EOD documents, such as Standard Operating Procedures, instructions, power point briefings, and draft documents proposing the future use of maritime robotics. Other documents reviewed during data collection focused on the historical use and threat of the MIED. Research also focused on the policy and doctrine concerning the ability of DOD to work with other agencies, such as the DHS, when facing the MIED and maritime security threat. This allowed for extensive background research such as historical facts and doctrine analysis. An advantage of reviewing these documents is that the information already exists and is verifiable.

Some disadvantages of this methodology are the information may be inapplicable, disorganized, unavailable, or out of date. A lot of information concerning MIEDs is located on the classified Secret Internet Protocol Router Network (SIPRNet) and other classified sources, which inherently is a disadvantage during research and documentation. This thesis does not include classified information.

Description, Analysis, and Interpretation

Applying Wolcott's methodology, there are three major dimensions to the information collected during qualitative research that help turn it in to usable data. He describes this process as transformation of qualitative data. It consists of description, analysis, and interpretation (Wolcott 1994, 6). Description addresses the question, "What is going on here?" analysis looks at how things work, and interpretation focuses on the meaning (Wolcott 1994, 12). This thesis uses this approach to transform the qualitative information collected into analysis. It will be discussed in further detail to gain an understanding of this approach, and how it applies to this research.

Description

Description is a way of organizing and presenting the information collected during research. One technique that Wolcott suggests is progressive focusing. This is especially useful when a specified problem is the focus of research. As the name suggests, it progressively zooms in from a broad context to the particular focus of the problem (Wolcott 1994, 18). Descriptions of the information collected are presented in Chapter 2, Literature Review, of this thesis. Analysis and interpretation are accomplished in chapters 4 and 5.

The first step of implementing this methodology in this thesis is to present the broad historical context of the adversary's tactics, techniques, and procedures through documented historical and current MIED incidents. The second step is to present DOD and interagency policy and agreements. The third step narrows its focus to Navy and Navy EOD doctrine for response in the maritime environment. The fourth and final step used for description in this thesis focuses on potential solutions to counter the MIED threat.

Analysis

Analysis is any form of transforming data to include management and ways of reporting. Wolcott describes analysis as a "systematic procedure followed in order to identify essential features and relationships" within the research topic (Wolcott 1994, 24). There are many types of analysis, but this research thesis will focus predominantly on using logical analysis, consisting of document analysis, domain analysis, and comparative analysis (Wolcott 1994, 31). Chapter 4 will present the findings and evaluation of analysis on the MIED threat, assess a capability gap in C-MIED operations,

propose potential solutions from a DOTMLPF framework, and assess the solution that could best counter this threat.

Logical analysis is the overall framework for chapter 4. It is a systematic approach utilizing the broad to narrow description approach. For this thesis, the logical approach to countering a MIED is reviewing and analyzing the threat, Navy EOD doctrine, policy, and materiel. The logical approach is applied when determining a capability gap and the acceptability, suitability, feasibility of a DOTMLPF solution for countering MIEDs.

The first analysis done in the logical analysis flow is the document analysis. This step of analysis is the principal source of analysis for identifying data to support options in countering the MIED threat. As mentioned previously, published and non-published documents were analyzed during this research. These documents will set the foundation for making the logical and comparative assessments in chapter 4.

Domain analysis refers to analyzing the maritime domain or the threat. After reviewing and analyzing the documents presented in chapter 2, an analysis of the threat is presented in chapter 4. A summary of the MIED attacks are presented in Appendix A.

Comparative analysis is used in chapter 4 when looking to identify a capability gap using the DOTMLPF framework. This will narrow the focus for a solution to one of the four domains being assessed by this research: DOTM. The existing leadership, personnel, and facilities is not being considered in the evaluation of a capability gap in countering MIEDs because these factors will not minimize or eliminate the tactical risk to the EOD operator. The LPF framework supports C-MIED operations and will not close the gap in safely responding to MIED in the contemporary maritime environment. Any

possible solution will be further narrowed towards a final solution through a comparison analysis. Once a final solution to the capability gap is determined, it will be compared to the researcher's theoretically ideal solution, described by the desired attributes identified in the evaluation criteria. The comparative analysis will help determine the best-suited solution for countering the MIED threat.

A comparative analysis of the DOTM framework will evaluate areas for a potential solution. If a capability gap is identified in one of the DOTM domains, criteria for comparing and analyzing will be applied to the possible solutions in countering MIEDs in the contemporary maritime domain.

Potential solutions will be subject to screening criteria to assess if additional research and analysis is required. Screening criteria will be broken down into acceptable, suitable, and feasible. To summarize, the three criteria this thesis will use to screen the materiel solutions:

1. Acceptable–Does the solution provide enhanced safety in terms of standoff distance and physical protection to EOD technicians?
2. Suitable–Does the solution enhance capabilities for countering the MIED threat?
3. Feasibility–Is the solution realistic and reasonable in the projected operational environment and the required operational conditions?

If a solution fails to pass all three screening criteria, it will not be analyzed further as a viable option for countering the MIED threat. The solutions that pass the screening criteria will be examined in greater detail to determine the most acceptable, suitable, and feasible.

Interpretation

Wolcott says interpretation marks "a threshold in thinking and writing at which the researcher transcends factual data and cautious analyses and begins to probe into what is to be made of them" (Wolcott 1994, 36). Interpretation presents the meaning of the research. For this thesis, it will explain the MIED as a threat in the maritime domain. With MIEDs being a threat in the contemporary maritime environment, this research will in turn recommend a counter method from an EOD perspective. These findings are presented in chapter 5 with the conclusion and recommendation.

Wolcott makes eleven suggestions on how to come up with interpretation, but it is up to the researcher to make the interpretation and the meaning of the research. One technique he suggested, which is used in this thesis, is connecting with a personal experience and personalizing the interpretation (Wolcott 1994, 44). As the researcher, I can draw on my experience in Iraq and the use of land robotics in countering IEDs. As suggested by several authors in chapter 2, lessons learned from over a decade of combat operations and the use of land robots in countering IEDs should not be lost when attempting to counter the MIED threat in the maritime domain.

Summary and Conclusion

Chapter 3 describes the detailed research methodology used for developing analysis and interpretation presented in chapters 4 and 5. Before starting this research, the problem and research questions were defined. Data collection for this research topic was predominately documentation review. The collected data is transformed during chapter 4 by applying analysis and developing a usable meaning of the data.

Chapter 4 analysis is critical for assessing and developing a counter to the MIED threat. It is the review of data and documents collected concerning current research and development of equipment for countering the MIED threat from the EOD aspect only. Analysis will also help identify overlaps and redundancies in research and capabilities. Finally, it provides an accurate MIED threat assessment used to analyze the capability gaps in current Navy EOD procedures and doctrine.

Chapter 4 also presents the interpretation of the data and analysis. Once there is an understanding of the potential operating environment and capabilities of the EOD unit conducting MIED operations, an assessment of the equipment they use is essential. Technical analysis of specifications on potential UUVs and ROVs will be done. A comparative analysis will propose several measures to interpret the value and meaning of the technical specifications. They will be based on the ability to provide safety for the technicians through standoff distance, optics, mobility, control and size. Knowledge gained through chapter 4's interpretation might suggest areas of improvement and development within Navy EOD MIED doctrine, TTPs, and training.

This research methodology should present a thorough analysis of historical and current trends of MIEDs and maritime terrorism. It should also present the Navy and other agencies with current capabilities and proposed future capabilities. This research will identify a capability gap in countering the MIED threat in the contemporary operating environment. It will address possible solutions to the capability gap through current tactics, equipment, training, and collaboration efforts. Based on this insight, recommendations will be made to help defeat the MIED threat.

CHAPTER 4

ANALYSIS

> Deployed surreptitiously underwater or delivered by suicide boats, IEDs in our ports and waterways could have chilling effects on the nation's trade–more than 90 percent of which is carried by ship and is critical for our globalized just-in-time and just-enough economy. Response to a domestic IED threat will be completely different from what U.S. forces handles overseas, as there are law-enforcement and infrastructure-protection concerns here that do not figure in military operations. (U.S. Navy 2009, 25)
>
> — Honorable Jay M. Cohen

> What keeps me up at night? The threat of water-borne IEDs. (U.S. Navy 2009, 13)
>
> — Admiral Thad Allen

Organization and Purpose

Chapter 4 is organized from a broad to narrow framework analyzing what was presented in chapter 2. It follows the logic presented in Figure 1. First, it will present the MIED, explaining why it is a threat in the contemporary maritime domain, and clearly identify the perceived capability gap. Next, it will look at the secondary research questions. The secondary research questions support answering the primary research question. Then it will answer the primary research question, which is how can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment? The purpose in answering the primary and secondary research questions is to identify and describe the substantial threat of maritime IEDs, and identify any shortfall in capabilities for Navy EOD in countering the threat. Using a modified DOTMLPF approach frames the areas to look at for possible solutions to a perceived capability gap. This research did not examine all possible DOTMLPF solutions, focusing on Doctrine,

Organization, Training, and Materiel aspects, and excluding Leader development, Personnel, and Facilities. LPF is being excluded because these factors will not minimize or eliminate the tactical risk to the EOD operator while looking at a capability gap in countering MIEDs. The existing leadership, personnel, and facilities support C-MIED operations and will not close the gap in safely responding to MIED in the contemporary maritime environment.

The subordinate research questions to help analyze potential solutions to a capability gap are:

1. What is the capability gap in the U.S. navy's existing ability to counter MIEDs?
2. Doctrine: What government and international agencies will the Navy need to work with to counter MIEDs nationally and globally?
3. Organization: What military units can EOD cross train with to close a capability gap?
4. Training: How could Navy EOD adjust TTP to counter the MIED threat more safely?
5. Materiel: What materiel solutions could provide the capabilities needed for countering the MIED threat?

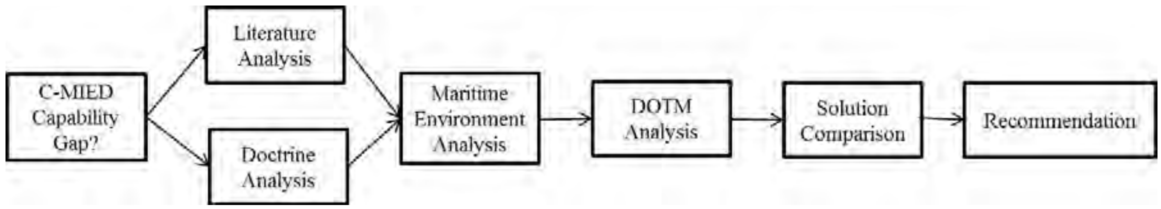

Figure 1. Logic Flow for Identifying a C-MIED Capability Gap

Source: Created by author.

The MIED Threat and the Presence of a Capability Gap

Water makes up approximately 70 percent of the world's surface. This means that the maritime domain is vast. The maritime environment presents an adversary with the advantage of stealth and surprise (Haealer 2010, 3). The detonation of a single MIED could have strategic consequences, which makes a MIED a concern in the contemporary environment of acts of terrorism and asymmetric warfare. Asymmetric maritime warfare has proliferated throughout the world because of the advantages and the effects. IEDs and MIEDs have proven to be cost-effective, adaptable, and significant in inflicting not only physical, but also psychological effects. To mitigate the strategic implications, maritime security and sea control are two of the U.S. Navy's pillars in the *Navy Operations Concept 2010* (U.S. Navy 2010).

Al Qaeda and its affiliate groups have already demonstrated an ability to exploit MIED as an asymmetric option. Shipping and container ships are vulnerable, as are key maritime infrastructures in U.S. ports. The maritime environment, including oceans, littorals, harbors, ports, and inland waterways, is of strategic importance to the security and stability of the United States (Prokopovich 2009, 39). A single attack could affect the

U.S. economy, and impose psychological effects on the American people similar to the affect after the 9-11 attacks and airline travel. There could be a decrease in maritime travel, increased security, delays in port shipping, and an increase cost in maritime shipping. Maritime targets are often considered “soft targets” due to the vast area to patrol and monitor. This is a vulnerability that could be exploited and have a detrimental impact. This was summarized by Admiral Walsh, Vice Chief of Naval Operations, in 2008 when he said, “The United States must be prepared for any potential terrorist activity in our ports, harbors and waterways, including threats from maritime mines and Underwater Improvised Explosive Devices [MIED]” (U.S. Navy 2009, 23).

The existence of a capability gap was presented in chapter 2. The Joint EOD Initial Capabilities Document states, “The capability to neutralize or remove explosive hazards relies upon the deployment by an EOD technician to perform a series of tasks, which may be independent or synergistically interdependent, and which require the employment of technology” (U.S. Navy 2014a, 9). The primary solution for response to a MIED is a manual approach of either a swimmer on the surface of the water or a diver in the water. The Navy EOD diver is currently the “primary in-service solution” (U.S. Navy 2014a, 5). This exposes the EOD technician to the blast and shock wave if a detonation occurs. A human is unnecessarily exposed to these risks. There is a gap in the capability of U.S. Navy EOD personnel to respond to MIED without exposing themselves to the risks caused by a manual approach to a suspected device in order to locate, identify, and render safe or dispose of the device. There could be a solution to close the capability gap and minimize the threat to Navy EOD divers while countering MIED threats.

Remaining Secondary Research Questions

Safety is paramount when responding tactically to an explosive threat. The asymmetrical threat of the MIED and the operational environment in which they are applied creates enormous challenges for a responding Navy EOD technician. The secondary research questions, following the DOTM framework, will help identify the area most likely to close the capability gap in responding to a MIED in the safest manner.

Doctrine

Secondary research question Number Two explores Navy doctrine and interaction with government and international agencies to counter MIEDs. This question addresses the "D" in the DOTMLPF approach. DOD and DHS have both realized the grave implications of a MIED detonation inside domestic waterways. The *National Strategy for Maritime Security*, *Maritime Operational Threat Response*, *Joint Publication for Homeland Defense*, and the *Navy Operations Concept 2010* provide the strategic level doctrine for countering the MIED (House 2005; DOD and DHS 2005; DOD 2013; U.S. Navy 2010). Each expresses the need for collaboration and coordination for maritime incidents, and even agrees to a joint chain of command for Homeland Security and Homeland Defense operations.

The aforementioned documents minimize a capability gap in doctrine and policy in terms of interagency and international coordination. Specifically, when it comes to international coordination, NATO's Maritime Command has taken charge of the maritime C-IED mission. This recognizes the worldwide threat of MIEDs on the global Sea Line of Communications (SLOCs). NATO's Maritime Command recognizes that "[k]ey lines of operation to counter the maritime IED threat include interagency

coordination to defeat the terrorist networks responsible for such attacks, raising awareness of the threat, training Naval forces on measures to protect against maritime IED attacks, and neutralizing or eliminating the maritime IEDs themselves, in whatever form they take" (NATO 2014).

Doctrine covers the responsibility of Navy EOD to respond to MIEDs. As the sole response force for underwater and floating IED devices, it is important to reinforce in Navy doctrine the importance of this mission. As of 2009, Coast Guard divers only had the capability to identify and mark underwater explosive threats, including MIEDs. The DHS diving instruction specifically states, "Coast Guard divers do not possess any Explosive Ordnance Disposal (EOD) capabilities and are not trained or equipped to perform Render Safe Procedures (RSP) on ordnance. Only qualified EOD divers shall attempt to render safe underwater ordnance or Improvised Explosive Devices (IEDs)" (DHS 2009, 1-10). This fact stresses the importance of the Navy EOD mission and the interagency coordination. Current doctrine answers the "who" questions, but does not address the "how" question of responding while protecting EOD responders.

Organization

Secondary research question Number Three looks at what organizations Navy EOD could cross train with to mitigate a gap in C-MIED operations. This question primarily addresses the "O" and aspects of "T" in the DOTMLPF approach. The organization of Navy EOD is adequate for conducting the mission of C-MIED operations. Navy EOD's current operational manning is at 94.1 percent, with eight Mobile Units, including two permanently deployed overseas (U.S. Navy 2015b). No additional units or assets are required. Enhancing EOD maritime operations with an

already existing capability from an outside organization might be a solution. As the littorals and coastal waterways gain increasing visibility among the Navy's leaders, integration with riverine forces appears to be a solution in countering MIEDs. The Navy's Coastal Riverine Force (CRF) operates in harbors, rivers, bays, across the littorals, and ashore. The mission of the CRF is to conduct maritime security operations across all phases of military operations by defending high value assets, critical maritime infrastructure, ports and harbors both inland and on coastal waterways against enemies, and when commanded, conduct offensive combat operations" (U.S. Navy 2015c). They also have an ability to insert and extract units in a maritime environment.

Integrating the CRF into EOD operations could allow EOD technicians to concentrate on conducting C-MIED operations instead of conducting boat operations. Currently, the EOD technician not only performs the diving operations, but they also man and maneuver the boat used as the dive platform. Utilizing CRF could free up EOD technicians from acting as the coxswain, and allow EOD to use a larger boat as the dive and operations platform. A typical EOD team operates using a seven-meter, rigid hulled boat while riverine units use a twelve-meter boat. The extra area could provide more room for operating and storage. It could allow for a larger range of materiel solutions as acceptable options.

Riverine and EOD are both subordinate units of the Navy Expeditionary Combat Command. Unity of command will allow for a much more fluid integration and coordination between the units. Navy EOD does not necessarily need to change the organization to continue operating against MIEDs, but performance and capabilities could be greatly increased by operating with units whose specific capabilities support the

C-MIED mission. Changes in organization could simplify the EOD technician's task, and could enable implementation of other potential solutions, but would not increase personal protection or standoff from a suspected MIED.

Training

Secondary research question Number Four evaluates TTPs used for C-MIED operations. This question addresses the "T" in the DOTMLPF approach. This thesis will not look at the overall training program of EOD. It will consider training in the context of TTPs as applied to real world response. To remain unclassified, this thesis will also not discuss specific technical TTPs, but will focus on the general TTPs related to personnel safety.

An important point when discussing TTPs is that the primary render safe task currently requires a physical approach from EOD divers (U.S. Navy 2014a, 3). This is also the case when EOD technicians work with the marine mammal systems (MMS). While the MMSs are able to find and mark the location of an explosive hazard, the EOD technician diving or swimming to the explosive hazard is still the primary means to place a counter explosive or tool to disarm such a device. This exposes the EOD diver to the explosive hazard and numerous additional hazards of the operational environment, such as dive sickness, dangerous sea state, aggressive marine life, and weather.

While training cannot eliminate the risk, an understanding of the expected operational environment can prepare an EOD team to react appropriately, and mitigate risk. Relating TTPs to training and looking at the previously described hazards, one can conclude that changes in training might narrow the identified capability gap, but not close the gap. Training alone cannot alleviate the dangers of a MIED and the requirement for a

human to approach in close proximity to an MIED in order to render it safe. A genuine solution appears to require something more than training to fulfill the capability gap in response to MIEDs.

Materiel

Secondary research question Number Five looks specifically at the potential for closing the capability gap with a materiel solution to conduct C-MIED operations. This question addresses the “M” in the DOTMLPF approach. A materiel solution analysis examines the equipment and systems that are desired to close the capability gap, and estimates how well such systems would close the identified gap. The potential materiel solutions in this research have been limited to maritime bomb suits, marine mammal systems, and robotics.

Chapter 2 identified several arguments that a capability gap exists when countering MIEDs. In this case, safety is the number one factor when examining the capability gap. A physical approach to a MIED by an EOD technician is a valid TTP, but places the human diver at risk from detonation, especially if the diver is submerged when the detonation occurs. A materiel solution could address safety with an increased standoff distance or physical protection from a detonation.

A maritime bomb suit could meet some of the requirements for a materiel solution toward filling the gap in response to the MIED threat. It would add protection while covering a range of operations, especially if designed for dual purpose, both sea and land. Currently, a comprehensive maritime bomb suit does not exist. As previously mentioned, the bomb suit on land provides protection from blast and fragmentation when operating in close physical proximity to IEDs. Using the same concept, a maritime bomb suit could

be developed that would provide an EOD technician significantly greater protection to manually approach a device while submerged or floating in the water.

Another materiel solution that already exists, and could be altered or enhanced to counter the MIED threat, is a MMS. As discussed in chapter 2, the marine mammal program is costly and facing phase out by the Navy (Guardian 2012). Instead of being phased out, the MMSs could be trained to locate, mark, and potentially neutralize MIEDs.

A third option the Navy is already looking at is a robotic solution to the MIED threat. The approach taken in land operations in Iraq and Afghanistan has robotics playing a primary role in locating, identifying, and rendering safe IEDs. Solutions already existed to protect EOD technicians in the environment ashore. In early operations, the bomb suit was the primary means of protection, but still did not provide standoff distance between the operator and the explosive threat. EOD robots already existed, but played a minimal role due to size and transportability. Maturing robotics technology enhanced user friendliness and robot capability. Subsequently, the role of robotics in C-IED operations increased to its current use today as the first option for an approach to an explosive threat. A similar approach taken to MIED solutions would recognize that some robotic solutions already exist, but should be enhanced to protect EOD divers.

Reviewing the Capability Gap

Countering the MIED threat in the contemporary maritime environment is the primary motivator for this research. While the TTPs of the manual hands-on approach by a Navy EOD technician exists, it is not the best possible solution. If the threat of MIEDs increases, the threat to EOD technicians also increases with the number of responses

conducted and the potential to increase the difficulty to disarm or render safe a MIED. A capability gap exists in conducting safe MIED operations, with current operations exposing EOD technicians to a potential MIED detonation. Exposure risk can be mitigated by increasing standoff distance, decreasing exposure time, and providing physical protection from a detonation.

Doctrine and organization were not assessed as able to close a gap in a capability to conduct significantly safer MIED operations. Doctrine and policy enable Navy EOD to conduct a full range of C-MIED operations, and establishes responsibilities both overseas and domestic, but do not address personnel protection. The DOTM framework also identified an inability for training to close the capability gap, indicating the need for a materiel solution. A materiel solution with corresponding TTP development that supports the materiel solution appears to be the best approach to filling the capability gap in C-MIED operations. With materiel as the perceived solution to closing the capability gap, the next step in narrowing the solution is to assess which of the three materiel solutions discussed in this thesis are most appropriate for achieving the desired end state for conducting C-MIED operations safely.

A maritime bomb suit should improve safety by providing greater protection to an EOD technician. The suit should be designed to float so a technician can approach from the surface of the water for floating MIEDs. Another important design feature would be the ability to dive to depth to disarm subsurface MIEDs. It could also address the possibility to protect from blast, fragmentation, and maritime conditions with a completely enclosed suit. The presence of a human operator compared to a non-human solution offers command and control over actions while conducting RSP procedures.

A maritime bomb suit still requires a human inside the potential blast and fragmentation area. In order to protect from the dangers of blast and fragmentation, the suit would most likely be cumbersome, especially to resist the shock wave and “gas bubble” caused by an underwater detonation. A comprehensive design would enable a technician to dive to depth. This would not reduce the dangers of diving injuries, such as decompression sickness, or exposure to aggressive marine life. Disadvantages of the maritime bomb suit therefore outweigh the advantages. Additional research and development might improve the performance of a maritime bomb suit, but existing technology does not identify this as a promising path for closing the capability gap.

Some advantages of the MMSs are the depth, distance, and speed at which the mammals can operate. This provides a standoff distance and minimizes the time on target for an EOD operator, at least during the locate and identify portion of an EOD operation. A handler has control over the MMS and cameras to allow the handler and technicians to observe what the MMS observes.

A major disadvantage of retraining the MMSs is it would take substantial time and money before becoming fully operational for use in a MIED environment. MMSs do not provide the desired dexterity in movement in and around a MIED where a fuzing and firing system is unknown. This places the MMS and the technicians at risk from a premature detonation. A MMS could also have difficulty conducting operations if the threat is a small boat MIED. The MMS does not have the ability to view or work inside a small boat and is primarily a subsurface tool for EOD technicians. The use of MMSs may still require an EOD technician to physically approach the device to disarm it. While a MMS could be a partial materiel solution to the capability gap posed by the MIED threat,

it would not provide a complete solution as it provides standoff for reconnaissance, but not necessarily for RSP.

A major advantage of a robotic solution is the capability to remotely render safe and neutralize the MIED with an increased standoff distance. This limits the dangers of exposure to blast and fragmentation to personnel. UUVs and ROVs can be manufactured to provide the dexterity and control required for operating on an unknown threat in which the slightest movement could detonate the MIED. A manipulator arm with a gripper hand would allow the robot operator to disarm or place a counter explosive charge on the MIED in order to neutralize the threat. A design that allows the robot to operate on the surface and extend the arm into the air would provide the capability to look inside a small boat used as a MIED. A robotic solution could cover a large range of potential MIED employment techniques from submerged, to surface, or boat-laden devices. An EOD technician might still be required to physically approach the device to manually disarm the MIED, but cameras on a robotic solution can provide the technician a greater understanding of the functioning and fuzing of the MIED and minimize the technician's time exposed its hazards.

Table 1. Materiel Solution Screening Criteria

	Criteria 1: Acceptable	Criteria 2: Suitable	Criteria 3: Feasible
Maritime Bomb Suit	No	Yes	Yes
MMS	No	Yes	No
Robotics	Yes	Yes	Yes

Source: Created by author.

Acceptable–Does the solution provide enhanced safety in terms of standoff distance and physical protection to EOD technicians?

Suitable–Does the solution enhance capabilities for countering the MIED threat?

Feasibility–Is the solution realistic and reasonable in the projected operational environment and the required operational conditions?

In summary, the marine bomb suit could provide protection from blast and fragmentation, but still requires an EOD technician to operate with a manual approach. This does not pass the first screening criteria. The MMS has the desired mobility based on operational reach, depth, and standoff during the initial reconnaissance of the MIED. This solution still requires a manual approach as well, and it therefore fails to pass the initial screening criteria (acceptable). The MMS also fails feasibility in the operational environment because of its inability to look or reach into a small boat. MMSs cannot operate across the range of military operations for the MIED threat. A robotic solution provides standoff throughout the complete range of operations from reconnaissance to render safe, which mitigates the need for a manual approach from EOD technicians. It is agile, has a high level of control, and the capability for defeating the array of employment techniques of MIEDs: subsurface, surface, or small boat. It overall enhances the capabilities to counter the MIED threat therefore; a robotic materiel solution is acceptable, suitable, and feasible. From the screening analysis of potential materiel solutions, a robotic solution is the only one that passes all three screening criteria.

Analysis of a Robotic Solution to C-MIED

Next, in the framework of broad to narrow this thesis will analyze current robotic solutions, the attributes and capabilities of each, and analyze which could best fill the

capability gap of EOD technicians safely conducting C-MIED operations. Five criteria will be used to evaluate a robotic solution: operating conditions, optics, mobility, control, and size.

A robotic solution should be able to operate with the greatest operational standoff range available. According to the *United States Navy Diving Manual, Revision 6,* a diver should not be exposed to more than 50 pounds per square inch (psi) while submerged (Naval Sea Systems Command and U.S. Department of the Navy. Systems 2009, 2-10). The standoff or distance required to achieve a 50-psi standard can be calculated using equations found in the diving manual. A MIED with 100 pounds of explosive would need a standoff of greater than 900 feet to achieve the 50-psi standard (Naval Sea Systems Command and U.S. Department of the Navy. Systems 2009, 2-9). Operational standoff distance is the most important factor in diver safety, but other criteria should be considered.

This research will examine the optics of the robot. The ability to see in lowlight and see further with optics will provide greater standoff and ability to examine the functioning of the MIED. TV Lines (TVL) is the standard for camera resolution measurement and a robotic solution should have a 450 TVL minimum. Greater TVL is better. While sonar capability of a robotic solution will be considered an optics capability, it is not ideal for providing detailed imagery for RSP procedures.

Mobility of the robot is its ability to operate on the surface and subsurface. The ability to do both is better; the benchmark is "both," and ability to operate at greater depths is also better. This expands the role of the robot, and mitigates the requirement for a swimmer or diver in certain situations.

Control over the robot is important. For this research, control is the ability to manipulate tools with the robot, to include an extending arm and gripper. An extending arm allows the robot to view inside and operate alongside an explosive laden boat MIED. The standard would be to have both a five-foot extendable arm to view inside a small boat with a gripper to be able to assist in neutralization, RSP, or disposal. This is important in today's contemporary environment; this mode of attack was employed against the USS *Cole*.

The last criteria is size, with a benchmark of 200 pounds, making the robot man-portable. Being man-portable allows Navy EOD teams to operate in their already established small units. A team of eight personnel should be able to deploy and operate the robot. No more than two technicians should be required to move and employ the robotic solution. To meet this criterion, a robotic solution should be limited in weight to no more than 200 pounds. This could also enable one team to employ multiple robots while operating out of a single boat.

The UUVs/ROVs will be assessed on the following five criteria:

1. Operating conditions: What is the operational standoff range? (> 900ft)?
2. Optics: What is the camera's ability in murky/lowlight area? (sonar and/or camera > 450 TV Line (TVL))?
3. Mobility: What is the ability to operate on the surface and subsurface? (one is acceptable both is optimal)
4. Control: What is the ability to manipulate? (extendable manipulator arm with gripper)
5. Size: Is it man portable? (Operated by 1–2 technicians)

Table 2. Comparative Analysis of Robotic Solutions to C-MIED

Robotic Solutions	Criteria 1: Operating conditions What is the operational standoff range?	Criteria 2: Optics What is the camera's ability in murky lowlight area?	Criteria 3: Mobility What is the ability to operate on the surface and subsurface?	Criteria 4: Control What is the ability to manipulate?	Criteria 5: Size Is it man portable?
MK 18 MOD 2	1970 ft (+)	No camera; only sonar (-)	Subsurface only (-)	N/A (-)	600 lbs (-)
MK 19 HULS	200 ft (-)	No camera; only sonar (-)	Surface and subsurface (+)	N/A (-)	174 lbs (+)
H300 MK II	985 ft (+)	450 TVL (+)	Surface and subsurface (+)	5 function manipulator arm (+)	155 lbs (+)
SeaBotix vLBV300	820 ft (-)	650 TVL (+)	Surface and subsurface (+)	Manipulator arm with gripper (+)	40 lbs (+)

* This is not an exhaustive list of all robotic solutions, but provides an array of what is currently being used.
(+) Meets benchmark criteria
(-) Does not meet benchmark criteria

Source: Created by author utilizing Bluefin Robotics, "Hovering Autonomous Underwater Vehicle," accessed 25 April 2015, http://www.bluefinrobotics.com/assets/Downloads/Bluefin-HAUV-Product-Sheet.pdf; ECA Group, "H300 MK II," accessed 25 April 2015, http://eca-media.ecagroup.com/player/pdf?key=f2e33e5aedf56d6f34e2a7d77dcd0be5f2e33e5aedf56d6f34e2a7d77dcd0be5; Hydroid, "Remus 600," accessed 25 April 2015, http://auvac.org/uploads/platform_pdf/remus600web.pdf; SeaBotix, "vLBV300," accessed 25 April 2015, http://www.seabotix.com/products/vlbv300.htm.

The MK 18 MOD 2 does not meet the benchmarks for four of the five analysis criteria. It has the largest operational standoff and could greatly enhance the reconnaissance and searching capability of EOD technicians responding to a MIED threat. It lacks a camera but does have sonar. This restricts its capability for high-resolution imagery and diminishes the ability to identify clearly all fuzing and functioning components of a MIED. The lacking in the ability to operate on the surface minimizes the effectiveness to subsurface MIEDs only and cannot operate in all domains a MIED could be found. Without an extendable arm or gripper, the MK 18 MOD 2 could have difficulty placing a counter charge on a MIED or removing key functioning items

from the MIED. Lastly, the weight is significantly larger than the criteria to remain man-portable. While it has a large standoff distance, the MK 18 MOD 2 fails to provide more than a searching capability when disarming a MIED. An EOD technician would still be required to place a counter charge or manually disarm the MIED.

The MK 19 HULS meets or exceeds two of the five analysis criteria. It has the shortest standoff distance and would only provide significant protection from smaller MIEDs. Similar to the MK 18 MOD 2, the MK 19 HULS does not have a camera and only provides imagery from sonar. It does have the ability to operate on the surface and subsurface, which expands its range of operations. It does not have an extendable arm with gripper and lacks the ability to place an explosive charge. This also limits its effectiveness while working on a small boat MIED. The size and weight meet the man-portable benchmark. The inability to place a charge, RSP, clearly identify components of the MIED, and work on an explosive laden boat would still require an EOD technician to manually approach to disarm the MIED.

The H300 MK II meets or exceeds all five criteria benchmarks. It has the potential to provide adequate standoff, visual imagery, and range of operations while being man-portable for two or less operators. The standoff and manipulator arm with gripper on the H300 MK II allows an EOD technician to operate all missions from search to RSP with a single robotic solution.

The SeaBotix vLBV300 meets or exceeds four of five criteria benchmarks. Although slightly short of the desired standoff distance benchmark, it is still another acceptable solution for C-MIED operations at the tactical EOD level. The standoff is slightly less than the benchmark of 900 feet but still provides a safe operating distance

while mitigating the need for a diver in the water who would be susceptible to the shock wave from a detonation. The camera would provide significant resolution for clearly identifying the fuze and functioning increasing the ability to RSP with solely the robot. The manipulator arm and gripper allows for placing an explosive charge to accomplish RSP. The size and weight significantly add to the ease of use for small teams and minimizes the operational footprint of the robot.

Summary and Conclusion

Chapter 4 analyzed the contemporary MIED environment, and offered the conclusion that MIEDs are a valid threat to maritime shipping, maritime security, and homeland defense. Maritime explosive devices are a concern of the DOD and DHS, as a single detonation could have strategic implications. Although not a new concept for asymmetric warfare, the MIED is still one that proves difficult to counter. The ease of making, procuring, and concealing these explosive devices in the vast maritime environment make them a concern at the strategic, operational, and tactical level. Navy EOD technicians are called upon to locate, render safe, and dispose of MIEDs, much like on land. Chapter 4 assessed the capability gap of the U.S. Navy EOD to conduct C-MIED operations without exposing technicians to risk through a manual approach. Chapter 4 then looked at the ability to close the identified capability gap in countering MIED using a DOTM, framework focusing on the tactical Navy EOD technician's ability to safely conduct counter MIED operations.

Chapter 4 interpreted and analyzed the data collected in chapter 2 and utilized it as the basis to make deductions in the DOTM framework. The DOTM analysis indicates that the identified capability gap could be only partially closed by changes in doctrine,

organization, or training, indicating a requirement for a materiel solution to close the existing capability gap in C-MIED operations. A comparative analysis of three potential materiel solutions –, a maritime bomb suit, Marine Mammal Systems (MMS), and robotics–indicated the robotic solution as most likely to close the gap.

Chapter 4 also analyzed and compared several existing robotic solutions. Criteria measures were established to interpret the value and meaning of the technical specifications. They were based on the ability to provide safety for the technicians through standoff distance, visual aid, mobility, control, and size. With the emphasis on safety, standoff distance is the most important of the five criteria. The H300 MK II and SeaBotix vLVB300 are very similar in capability, and could fill the capability gap in safely responding to and conducting counter MIED operations. Based on this study, the H300 MK II enhances Navy EOD capability the greatest, and emerges as a recommended solution.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

> The naval warfare environment is rapidly changing. The U.S. Navy is adapting by continuing its blue-water dominance while simultaneously building brown-water capabilities. Unmanned systems, such as unmanned airborne drones, are proving pivotal in facing new battlefield challenges. Unmanned underwater vehicles (UUVs) are emerging as the Navy's seaborne equivalent of the Air Force's drones.
>
> — Richard Winston Larson,
> *Disruptive Innovation and Naval Power*

Organization and Purpose

A threat from the MIED exists in the contemporary maritime environment. There is a capability gap in safely conducting C-MIED operations at the tactical operator level. The solution to the capability gap is found using the DOTMLPF framework. In this thesis, it was found to be a materiel solution. Comparing three potential solutions found that a robotic solution is the most logical. While some commercial off the shelf solutions already exist, there are some gaps in the robotics solution's ability to conduct a full range of C-MIED operations. Chapter 5 examines the recommended robotic solutions and future studies that could further close the gap in countering the asymmetric MIED threat.

Chapter 5 is organized by restating the purpose of this research thesis and providing a synopsis of previous chapters and findings. It will also present recommendations from the researcher based on the analysis of chapter 4. These recommendations directly answer the primary research question, and are supported by the secondary research questions. Chapter 5 proposes several future research studies that are either directly tied to chapter 4's analysis and recommendations in this chapter, or areas

that support and enable the primary research question. Lastly, it will express the importance of this research and a final thought on MIEDs.

MIEDs are a form of asymmetric warfare in today's environment. These devices can have a strategic impact effecting international shipping, target the military, and domestic terrorism effects similar to the 9-11 attacks. The ability to counter these devices is crucial to accessing the contemporary maritime environment. At the tactical level, Navy EOD technicians are called upon for the mission of conducting C-MIED operations. The array of MIEDs and the vastness of the world's waterways make for an unsafe operating environment. Safety of EOD technicians is paramount when conducting C-MIED operations. For this reason, the primary thesis question is how can Navy Explosive Ordnance Disposal counter the MIED threat in the contemporary operational environment?

Several subordinate research questions that assist in analyzing the topic in a DOTM framework are:

1. What is the capability gap in the U.S. navy's existing ability to counter MIEDs?
2. Doctrine: What government and international agencies will the Navy need to work with to counter MIEDs nationally and globally?
3. Organization: What military units can EOD cross train with to close a capability gap?
4. Training: How could Navy EOD adjust TTP to counter the MIED threat more safely?

5. Materiel: What materiel solutions could provide the capabilities needed for countering the MIED threat?

Chapter 1 posed the research questions and frames the discussion of the thesis and point of view in which it is written. Chapter 2 reviewed the background and historical data of MIEDs to propose that they are a probable maritime threat in the contemporary environment. It also looked at policy of the DOD and DHS that recognizes MIEDs as a threat, and the importance of developing security measures to counter the threat. Doctrine concerning Navy EOD's role in responding to the MIED threat was reviewed to understand their capabilities. Chapter 2 also looked at current and future equipment and TTPs for countering the MIED threat from the EOD technician's perspective. Chapter 3 described the research methodology used throughout this thesis, a post-modern perspective to qualitative research. It articulated the process for collecting, analyzing, and interpreting the qualitative data. It laid the foundation for chapter 4, and the process of taking a broad focus, narrowing it down to answer the primary and secondary research questions. Chapter 4 applied analysis and interpretation of the data collected and presented in chapter 2. Chapter 4 answered the primary and secondary research questions, and identified a capability gap in safely countering the MIED in the contemporary maritime environment. Modifications to doctrine, organization, or training could not close the capability gap, so a materiel solution was found to be the most practical to meet the desired end state for safely conducting C-MIED operations. Of the three options considered (a maritime bomb suit, a marine mammal system, or a robot), the robotic solution was the only one that met all three screening criteria of acceptable, suitable, and feasible.

Recommendations

The following are recommendations based on qualitative research and analysis within the scope of this thesis. They are also based on the research fact that MIEDs will continue to be a threat and possibly increase in practice. There is an established capability gap in conducting C-MIED operation and chapter 4's analysis and interpretation that leads one to believe that a robotic solution is desired for fulfilling the gap in safely combating the MIED at the tactical level threat. Although robotic solutions already exist, they can be improved upon to meet the range of operations and environment that an adversary can employ MIED. Attributes that already exist in robots to counter the IED threat on land can be applied to specifications to meet the maritime robotic needs. These attributes are speed, range, control, dexterity, ability to manipulate, towing capability, optics, and remote control. These should also be considered when developing an optimal solution for the MIED threat with the addition of depth, floatation, an arm length to look inside small boats, and an ability to place a counter charge to neutralize the MIED.

After conducting research and analysis for a materiel solution and several already-existing robotic solutions, the following specification is recommended for a robotic solution. The specifications are a combination of the H300 MK II and SeaBotix vLBV300 features to maximize the key features of each. The addition of an extending arm to five feet is for the enhanced ability to view inside and disarm MIED inside a boat.

Table 3. Recommended Maritime Robot Specification					
Robotic Solutions	Criteria 1: Operating conditions What is the operational standoff range?	Criteria 2: Optics What is the camera ability in murky lowlight area?	Criteria 3: Mobility What is the ability to operate on surface and subsurface?	Criteria 4: Control What is the ability to manipulate?	Criteria 5: Size Is it man portable?
Recommended	900+ ft	> 450 TVL	Surface and subsurface	Manipulator arm with >5ft extending gripper w/ camera	<100 lbs
H300 MK II	985 ft	450 TVL	Surface and subsurface	5 function manipulator arm	155 lbs
SeaBotix vLBV300	820 ft	650 TVL	Surface and subsurface	Manipulator arm with gripper	40 lbs

Source: Created by author utilizing ECA Group, "H300 MK II," accessed 25 April 2015, http://eca-media.ecagroup.com/player/pdf?key=f2e33e5aedf56d6f34e2a7d77dcd0 be5; SeaBotix, "vLBV300," accessed 25 April 2015, http://www.seabotix.com/products/vlbv300.htm.

In order to explore the robotic solution for C-MIED operations thoroughly, it is recommended to survey Navy EOD technicians for attributes they desire for the "tool" they will use in a non-permissive environment. It is important to get feedback and insight from the personnel who will be using the robot and placing their lives in harm's way. The different experiences of EOD technicians, if captured and provided for consideration during development and selection would enable the development of a well-rounded and versatile UUV or ROV.

Future Studies

A comprehensive quantitative study of robotic solutions is recommended. The future study could look at the attributes presented in this thesis, and the tangible functionality in the operational environment. A consideration during functionality is the ability to conduct port protection using UUV/ROVs. Speed of the robot is additional

feature that could be considered when conducting a quantitative study. Speed could improve responsiveness and limit exposure time on target, and how long the MIED will be a threat for the EOD technicians. One aspect presented during this research that could be further developed is integration with the combat riverine forces. While not a solution to the capability gap presented here, it could be researched as an enhanced capability for C-MIED responses. Lastly, while the tactical response to MIED operations is important, it is equally important to prevent and mitigate damage from a MIED attack. Shipboard reaction and countermeasures to a MIED attack should be explored to eliminate the asymmetric effect of the MIED.

Conclusion

Unmanned Underwater Vehicles (UUV) and Remotely Operated Vehicles (ROV) are possible tools for explosive ordnance disposal (EOD) technicians conducting underwater explosive operations. UUVs and ROVs provide safer standoff distances for personnel who attempt to counter maritime explosive threats. A perceived capability gap, identified in chapter 4, exists between the methods, techniques, and materiel the Navy currently uses and what it desires. Standoff, optics, mobility, control, and size are a few features to consider when selecting the proper tool. Standoff provides the operator a safe distance between themselves and the threat and dangers of a detonation. Optics offers a view of the explosive threat that otherwise might only be seen through a manual approach. Another critical feature is mobility and the robots ability to operate on the surface and under the water. This ability can allow the EOD technician to address both underwater devices and floating devices, which are common adversary Tactics, Techniques, and Procedures (TTP) for MIEDs. Control is an enhanced capability that

includes the addition of a gripper claw and arm on the vehicle that enables the operator to remotely grip, pull, and push when desired. Mobility combined with control allows the EOD technician to manipulate the UUV or ROV with precision when placing a counter-explosive charge or rendering the MIED safe. Size is critical because space is limited on the dive platform or boat. Limiting the size allows the robot to be man-portable for small Navy EOD response teams.

Future enemies of the United States could employ MIEDs to disrupt the maritime domain. While Navy EOD has TTPs to respond, there is room for improvement in safety and protection from explosive threats. A DOTMLPF assessment can identify areas to help close the capability gap in safe execution in C-MIED operations with a materiel solution leading to a robotic solution the most likely for closing the capability gap. Identifying and recommending areas to improve and eliminate deficiencies in a diver-based underwater response to improve tactical response capability for Navy EOD in the maritime environment is essential to safely and efficiency in countering the MIED threat.

APPENDIX A

CONTEMPORARY MIED ATTACKS

Contemporary MIED Attacks			
Date	**Incident**	**MIED type**	**Group**
1990-2000	10 Attacks on Sri Lankan Navy	Small boat laden with explosives	Tigers of Tamil Eelam (LTTE)
2000	USS Sullivans (attempted)	Small boat (suicide)	Al Qaeda
2000	USS Cole bombing	Small boat (suicide)	Al Qaeda
2002	M/V Limburg bombing	Small boat (suicide)	Al Qaeda
2004	Attack on USS Firebolt boarding team	Small boat (suicide)	Unknown
2004	Al-Basra oil terminal attacks	Small boat (suicide)	Jamaat-al-Tawhid
2004	Lake Pontchartrain, LA USA	Floating MIED	Unknown
2008	SLN Dvora sunk	Improvised sea mine	LTTE
2008	MV Invincible	Suicide diver	Al Qaeda
2010	MV M-Star	Improvised limpet	The Brigades of Abdullah Azzam

Source: Created by author utilizing Peter Chalk, *The Maritime Dimension of International Security: Terrorism, Piracy, and Challenges for the United States* (Santa Monica, CA: RAND, 2008); Dr. Christopher Martin, “The Historical Use of Maritime Improvised Explosive Devices” (Occasional Paper No. 1, Hull University Centre for Security Studies IED Project, 2010); Dr. Marco D. Tomasi, “Water-borne IED Threats and the Strait of Hormuz” (JIEDDO J2 Global Information Research Center (GIRC), 2009).

REFERENCE LIST

Air Land Sea Application Center. 2011. FM 4-30.16 MCRP 3-17.2C NTTP 3-02.5 AFTTP (I) 3-2.32, *EOD Multi-Service Tactics, Techniques, and Procedures for Explosive Ordnance Disposal in a Joint Environment*. Washington, DC: Government Printing Office.

Bluefin Robotics. 2015. “Hovering Autonomous Underwater Vehicle.” Accessed 25 April 2015. http://www.bluefinrobotics.com/assets/Downloads/Bluefin-HAUV-Product-Sheet.pdf.

Boyle, Alan. 2003. “Dolphins go to the front lines in Iraq war.” *NBC News*. Accessed 7 March 2015. http://www.nbcnews.com/id/3078682/ns/technology_and_science-science/t/dolphins-go-front-lines-iraq-war/#.VPsmDZU5DIV.

Carnegie, Dale, and Rita Kiley. 1948. *How to Stop Worrying and Start Living.* New York: Simon and Schuster.

Causee, Christopher, Mark Ellis, Mike Hellard, Rich Jimenez, Jua Lim Cheng, Julio Nilsson, Bobby Rowden, Joel Wheatley, Eric Winn, and Tim Smith. 2008. “Systems Approach to Defeating Maritime Improvised Explosive Devices in US Ports.” Thesis, Naval Postgraduate School, Monterey, CA.

Chalk, Peter. 2008. *The Maritime Dimension of International Security: Terrorism, Piracy, and Challenges for the United States.* Santa Monica, CA: RAND.

Creswell, John W. 2003. *Research Design: Qualitative, Quantitative, and Mixed Method Approaches*. 2nd ed. Thousand Oaks, CA: Sage Publications.

Doherty, Ruth. 2009. *Critical Research/Innovation Focus Area Document: Detect and Defeat Waterborne Improvised Explosive Devices (WBIEDs)*. US Department of Homeland Security, Science and Technology Directorate.

Duffy, James P. 2008. *Lincoln's Admiral: The Civil War Campaigns of David Farragut*. New York: Castle Books.

ECA Group. 2015. “H300 MK II.” Accessed 25 April 2015. http://eca-media.eca group.com/player/pdf?key=f2e33e5aedf56d6f34e2a7d77dcd0be5.

The Guardian. 2012. “US Navy’s Mine-Hunting Dolphins will be Replaced by Robots in 2017.” December 3. Accessed 7 March 2015. http://www.theguardian.com/ world/2012/dec/02/us-military-replace-dolphins-robots.

Haealer, John M. 2010. “Sea Devils, Submersibles, and Underwater IEDs: Asymmetric Undersea Threats to Assured Access in an Operational Environment.” Paper, Naval War College, Monterey, CA.

Helmick, Jon S. 2008. "Port and Maritime Security: A Research Perspective." *Journal of Transportation Security* 1, no. 1: 15-28.

Hydroid. 2015. "Remus 600." Accessed 25 April 2015. http://auvac.org/uploads/platform_pdf/remus600web.pdf.

Jean, Grace V. 2008. "Improvised Explosive Devices: Could They Threaten U.S. Ports?" *National Defense Magazine*, January. Accessed 22 December 2014. http:www.nationaldefensemagazine.org/archive/2008/January/pages/improvised2385.aspx.

Larson, R. W. 2014. "Disruptive Innovation and Naval Power: Strategic and Financial Implications of Unmanned Underwater Vehicles (UUVs) and Long-Term Underwater Power Sources." PhD diss., Massachusetts Institute of Technology.

Martin, Dr. Christopher. 2010. *The Historical Use of Maritime Improvised Explosive Devices.* Occasional Paper No. 1, Hull University Centre for Security Studies IED Project.

Military Intelligence Service. "Facts About Blast, and Shock Waves in Water." *Intelligence Bulletin* 2, no. 11 (July 1944): 78-85. Accessed May 4, 2015. https://archive.org/stream/1944-07IntelligenceBulletinVol02No11#page/n81/mode/2up/search/blast.

National Commission on Terrorist Attacks. 2004. *The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks upon the United States.* New York: W. W. Norton and Company. Accessed 30 August 2010. http://www.9-11commission.gov/report/911Report.pdf.

Naval Sea Systems Command and U.S. Department of the Navy. *United States Navy Diving Manual, Revision 6*. Washington, DC: Claitor's Law Books and Publishing, 2009.

North Atlantic Treaty Organization (NATO). 2014. *MARCOM Takes Charge of NATO Maritime C-IED Mission*. Northwood, UK: NATO.

Prokopovich, Paul. 2009. "The Role of the Naval Services in Irregular Warfare." Research Paper, Air War College, Maxwell AFB, AL.

Reynolds, Thomas. 2013. "Learning from IEDs." *Proceedings* 139, no. 8 (August): 54-59.

SeaBotix. 2015. "vLBV300." Accessed 25 April 2015. http://www.seabotix.com/products/vlbv300.htm.

Sulfredge, C. David, Robert H. Morris, and Robert L. Sanders. 2001. *Calculating the Effect of Surface or Underwater Explosions on Submerged Equipment and Structures.* Oak Ridge, TN: Center for Structural Molecular Biology. National

Laboratory. Accessed 1 March 2015. http://csmb.ornl.gov/~webworks/ cppr/y2001/pres/123612.pdf.

Sun Tzu. *The Art of War*. Translated by Samuel B. Griffith. London: Oxford University Press, 1971.

Tan, Andrew T. H. 2010. *The Politics of Maritime Power: A Survey.* London: Routledge.

Thompson, Jeremy. 2013. "Defeating IEDs with USVs." Naval Drones. Accessed 22 December 2014. http://blog.navaldrones.com/2013/06/defeating-ieds-with-usvs.html.

Thompson, Laura J. 2011. "US Maritime Security: Sustainability Challenges." Thesis, Naval Postgraduate School, Monterey, CA.

Tomasi, Dr. Marco D. 2009. "Water-borne IED Threats and the Strait of Hormuz." JIEDDO J2 Global Information Research Center (GIRC).

Tomkins, Richard. 2014. "U.S. Taps Saab for Remotely Operated Vehicle to Counter Maritime IEDs." UPI. Accessed 22 December 2014. http://www.upi.com/ business_ news/security-industry/2014/10/29/us-taps-saab-for-remotely-operated-vehicle-to-counter-maritime-ieds/2391414601941/.

Truver, Scott C. 2008. "Mines and Underwater IEDS in US Ports and Waterways: Context, Threats, Challenges, and Solutions." *Naval War College Review* 61, no. 1 (Winter): 106-127.

U.S. Department of Defense. 1992. AR 75-14 OPNAVINST 8027.1G MCO 8027.1D AFR 136-8, *Interservice Responsibilities for Explosive Ordnance Disposal*. Washington, DC: Government Printing Office.

———. 2013. Joint Publication 3-27, *Homeland Defense.* Washington, DC: Government Printing Office.

U.S. Department of Defense and U.S. Department of Homeland Security. 2004. "Memorandum of Agreement between the Department of Defense and Department of Homeland Security for Department of Defense Support to the United States Coast Guard for Maritime Homeland Security." Washington, DC.

———. 2005. *National Strategy for Maritime Security: Maritime Operational Threat Response Plan.* Washington, DC: Department of Homeland Security

U.S. Department of Homeland Security. 2009. *Coast Guard Diving Policies and Procedures Manual: COMDTINST M3150.1C*. Washington, DC: Department of Homeland Security.

———. 2011. *Small Vessel Security Implementation Plan Report to the Public*. Washington, DC: Department of Homeland Security.

U.S. Navy. 2009. "21st Century U.S. Navy Mine Warfare: Ensuring Global Access and Commerce." Accessed 7 March 2015. http://www.navy.mil/n85/miw_primer-june2009.pdf

———. 2010. *Naval Operations Concept 2010: Implementing the Maritime Strategy*. Washington, DC: Government Printing Office.

———. 2014a. *Draft-Maritime Explosives Response Roadmap*. Washington, DC: Government Printing Office.

———. 2014b. *Naval Responsibilities for Explosive Ordnance Disposal Program and Mission Support: OPNAVINST 8027.1H*. Washington, DC: Government Printing Office.

———. 2015a. "Marine Mammal Program." Accessed 7 March 2015. http://www.public.navy.mil/spawar/ 04Pacific/71500/Pages/faqs.aspx.

———. 2015b. "Navy Bureau of Personnel Command." Accessed 25 April 2015. http://www.public.navy.mil/bupers-npc/enlisted/community/specwarops/Documents/E200_EOD_MAR2015.pdf.

———. 2015c. "Navy Expeditionary Combat Command." Accessed 8 March 2015. http://www.necc.navy.mil/.

U.S. Navy, US Marine Corps, and US Coast Guard. 2007. *A Cooperative Strategy for 21st Century Seapower*. Washington, DC: Government Printing Office. Accessed 3 January 2015. http://www.navy.mil/maritime/MaritimeStrategy.pdf.

Vanguard. 2010. "Request for Bids–EOD 9 Bomb Suit, Helmet, and Visor." Accessed 7 March 2015. http://procurement.ncrpc.org/HS/South%20Central/2010/BombSuit_BidDocs.pdf.

Weinberger, Sharon. 2012. "Robots Replace Costly US Navy Mine-Clearance Dolphins." *BBC*. Accessed 7 March 2015. http://www.bbc.com/future/story/20121108-final-dive-for-us-navy-dolphins.

White House. 2005. *The National Strategy for Maritime Security*. Washington, DC: The White House.

Wolcott, Harry F. 1994. *Transforming Qualitative Data: Description, Analysis, and Interpretation*. Thousand Oaks, CA: Sage Publications.